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UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
College of Agriculture, University of Wisconsin

DEPARTMENT BULLETIN No. 1256

Washington, D. C. ▼ October 13, 1924

TOBACCO DISEASES AND THEIR CONTROL

By

JAMES JOHNSON, Agent, Office of Tobacco Investigations
Bureau of Plant Industry, and Professor of Horticulture
College of Agriculture, University of Wisconsin

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INTRODUCTION.

The tobacco plant has been cultivated in the United States for more than 300 years. Nearly 1,750,000 acres of land are devoted to the production of the crop, which is now approximately one and one-third billion pounds per year. While new areas have been gradually opened to the culture of the crop, the growing districts have remained remarkably constant in location, so that most tobacco soils are subject to continuous or repeated intensive culture, naturally resulting in an accumulation of diseases and insects which affect this crop in particular. The production of a good yield and high quality of tobacco up to the manufacturing stage has become increasingly difficult, in spite of the greatly increased knowledge and experience on the part of the growers concerning the various aspects of the culture of the crop. Some of the most important and obscure difficulties confronting the growers are those which belong to the class of plant diseases. It is the purpose of this bulletin to describe these diseases, giving the causes where known, and to suggest the best means of control available.

The tobacco-growing districts are relatively small areas, located largely east of the Mississippi River, but ranging from the warmest to almost the coolest climate in the United States (fig. 1). These districts, furthermore, produce distinct types of tobacco, used for various purposes, as a result of employing different varieties of seed,

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growing the crop on widely different soils, together with variations in climatic conditions and methods of handling. The main problems confronting the growers in the different sections, therefore, are not always the same. Any one disease may be much more serious

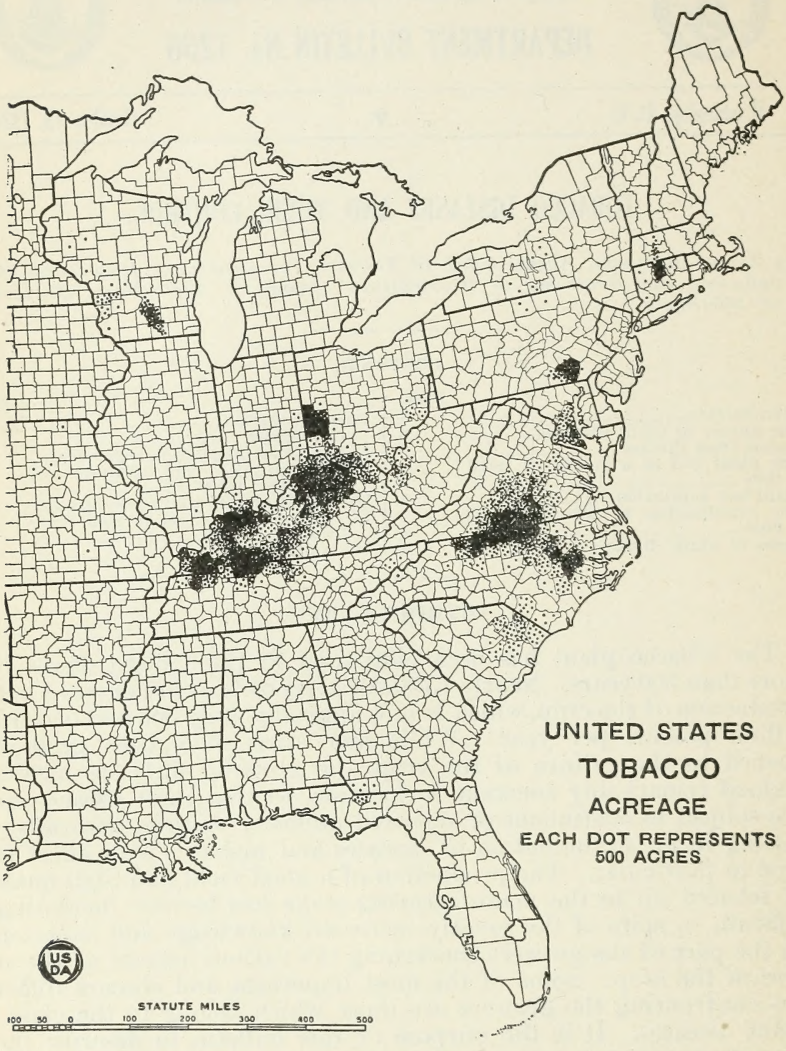


FIG. 1.—Map of the eastern half of the United States showing the tobacco-growing districts. Intensive culture in relatively small districts is favorable to the accumulation of plant diseases.

in one section than in another or may not occur at all in some districts, either because of conditions of environment or varietal differences in resistance or due to the accident of introduction of the parasite concerned. The control measures recommended therefore may not apply equally well to all districts, but these details can not be given full consideration in a brief treatise on the subject.

THE NATURE OF PLANT DISEASES.

Before giving separate consideration to each disease it is well to recognize the general facts in regard to plant diseases and their control.

The most fundamental consideration to be borne in mind is that most of our plant diseases are caused by fungi or bacteria (germs). These organisms (Pl. I, figs. 1 and 2), usually so extremely small in size that they can be seen only with high-power microscopes, are capable of attacking and feeding upon plant tissues, thereby injuring the plant. The particular organism causing the injury is called the parasite, and the plant attacked is conveniently referred to as the host. Each parasite usually produces a distinct type of injury, so that it is ordinarily possible to recognize the disease readily by the general symptoms. In the case of most diseases caused by parasites it is possible to isolate the fungus or bacterium concerned and to grow it in pure culture, that is, free from all other living organisms, and thereby study many aspects of its character and behavior. By inoculating plants with such cultures it is possible to prove positively that the organism is the cause of the disease in question and to study many problems bearing on the control of the disease.

Diseases of the above-described type are infectious, that is, under favorable conditions they can spread from one plant to another. They may be harbored in the soil, or by certain agencies may be carried over unfavorable periods for infection and later spread to susceptible plants which become diseased, environmental conditions permitting. The part played by weather conditions in plant diseases is an important one, but from the standpoint of disease control is of little importance, since weather can not be controlled. About the only practical method for the control of plant diseases is therefore that of preventing infection either by eliminating the parasite or else by safeguarding the host plants from its attack by spraying or by the use of resistant varieties.

A second class of plant diseases are those generally referred to as the nonparasitic group. Such diseases are either known to be or believed to be not due to parasites but result rather from unfavorable soil or climatic conditions which disturb the normal progress of plant development. Several other types of injury may be included here, however. The principles of control are therefore radically different from those used against parasitic diseases.

Another class of troubles which must be considered in the case of tobacco and which strictly does not fall into either of the above classes is damage occurring during the curing, fermenting, or storage processes, when the plant tissue is dead. While these troubles usually are of the same nature as the parasitic diseases, in that they are due to fungi and bacteria, the organisms concerned are termed saprophytes because they live and grow normally on dead tissue.

Insect damage is not considered in this bulletin except in so far as it plays a part in spreading plant diseases.

LOSSES FROM DISEASE.

The annual losses caused by diseases of tobacco in the United States are difficult to estimate with any degree of accuracy. Fairly

careful study of some diseases in certain sections at one time or another furnishes some basis, however, for the conclusion that the average annual loss amounts to many millions of dollars. The losses from root rots in certain years certainly exceed $10,000,000. Some of the recent wild-fire and black-fire epidemics have alone caused losses to the extent of millions of dollars in certain districts. Other leaf-spot diseases and mosaic are always present to a considerable extent in one section or another and materially reduce both yield and quality. The damages during curing and fermentation alone run into hundreds of thousands of dollars annually. If we estimate the average annual loss from tobacco diseases in the United States at 5 per cent of the crop value, which is believed to be a very conservative figure, the loss based on the present value of the crop would be close to $25,000,000 per year.

THE PLANT BED AS A SOURCE OF INFECTION.

A very considerable number of diseases which cause great damage in the field have their origin in the plant bed. Preventive measures should, therefore, be used in the preparation of the seed beds to assure success in controlling the diseases in question. The most common seed-bed disease is known as damping-off or bed-rot and may be caused by several different fungi. The parasites of this class are, however, ordinarily important only in the seed beds, although they may occasionally carry over into the field as black-leg, canker, or sore-shin.

In the case of black root-rot the most serious injury follows transplanting to infested soils, although frequently much injury results from the occurrence of this disease in plant beds and the subsequent transplanting of infected plants to disease-free soils.

The mosaic disease of tobacco, which is very rarely noted or regarded as of any importance in the plant beds, usually originates, however, in the seed beds, and its presence there is largely responsible for the general field infections frequently observed in many sections.

Recently it has been shown that several bacterial diseases, i. e., wild-fire, black-fire, and Wisconsin leaf-spot, some of which are very important in the districts where they occur, are in practically all cases traceable to plant-bed infection. Many other diseases of tobacco may also make their first appearance in the seed bed.

The production of plants for transplanting entirely free from such diseases as mosaic, wild-fire, and black-fire is therefore highly important, since at no other point can the prevention of these diseases be accomplished more efficiently or economically.

The principles of control are essentially similar for all the diseases concerned, that is, eliminating the chances of the introduction to the seed bed of the parasites concerned in these diseases or destroying them if already present. The measures which can be applied can be included under the general term "sanitation."

PLANT-BED SANITATION.

The following summary of sanitary measures which should be applied in seed-bed preparation, particularly on farms where mosaic

or the bacterial leaf spots have recently caused concern, is presented. In the case of damping-off and root-rot the use of new soil or sterilized soil will ordinarily suffice.

(1) Plant beds should preferably be placed a considerable distance from the location of the seed beds or fields of the previous year and away from tobacco-curing barns and weedy areas.

(2) No tobacco refuse (trash) or stems should be used as fertilizer on seed beds. Refuse should preferably be cleaned up and destroyed before seed beds are started.

(3) Plant-bed frames should be made of new material, or the old material should be disinfected by painting or sprinkling with some disinfecting solution such as formaldehyde or corrosive sublimate.

(4) If new seed-bed covers are not used, the old cloth covers should be sterilized by boiling one hour, and sash should be disinfected with the frames.

(5) If new land is not used for seed beds—i. e., woods lands, new breaking, or sod—the soil for the seed beds should be sterilized, preferably by steaming for at least 30 minutes.

(6) In case the tobacco seed to be used is likely to be infested with wild-fire or black-fire it should be disinfected with corrosive sublimate (1 part to 1,000 parts of water). Place the seed in a cheesecloth bag, dip it in the solution, and stir it about for 10 to 15 minutes. Rinse thoroughly with pure water and dry as rapidly as possible. This method of sterilization can be used only with seed sown in the soil without previous sprouting, since sprouting is otherwise interfered with. Silver-nitrate (1 to 1,000) treatment for 15 minutes gives as good disinfection as corrosive sublimate and permits sprouting of the seed before sowing.

(7) Do not sow the seed too thickly (1 ounce to each 800 to 1,000 square feet is usually sufficient). Do not overwater the plants, and ventilate frequently by raising or removing the covers, especially when glass covers are employed.

(8) Inspect the beds at intervals for diseased plants, and if any are noted destroy them at once and soak the infected area with formaldehyde solution (1 to 25). Carefully avoid these infected areas when weeding or pulling plants, since the parasites are readily spread at such times. If infection is general in the seed bed it is safest to procure healthy plants from other sources for transplanting.

THE STERILIZATION OF SOIL FOR PLANT BEDS.

The sterilization of seed beds by steam, using the inverted-pan method, gives the most satisfactory results (fig. 2). Surface firing, roasting, and the formaldehyde-drench methods are useful under certain conditions or in the absence of facilities for steam sterilization. The principal benefits of soil sterilization are the killing of parasites which may be harbored in the soil, such as those which cause damping-off and root-rot, and the killing of weed seeds. By bringing about other changes in the soil, however, a considerably more uniform and rapid growth of the seedlings ordinarily results (fig. 3).

To steam beds by the inverted-pan method, a boiler, pan, and connecting hose or pipe are required. The boiler should have sufficient capacity to discharge a continuous flow of steam at a pressure of at

least 80 pounds into the inverted pan. While the pressure in the pan itself may be considerably less than a pound, the advantage in high pressure lies in the fact that dry steam is preferable to wet steam and in that through a small connecting hose more steam can be supplied to the pan per minute. The ordinary steam traction engine, when obtainable, is especially suitable for this work.

The pan is preferably made of No. 16 galvanized iron reinforced with angle iron, although other materials may be used. Its size, shape, and construction may be made to fit the conditions at hand. The pan may ordinarily vary from 50 to 100 square feet in area, 6 by 12 feet by 8 inches in height being common dimensions, although pans as long as 14 and 16 feet are used. Handles, usually of iron pipe, are ordinarily attached. The lower edge of the pan should be sufficiently sharp so that it may be pressed readily into loose soil. The inlet for the steam may be made through the top or side of the

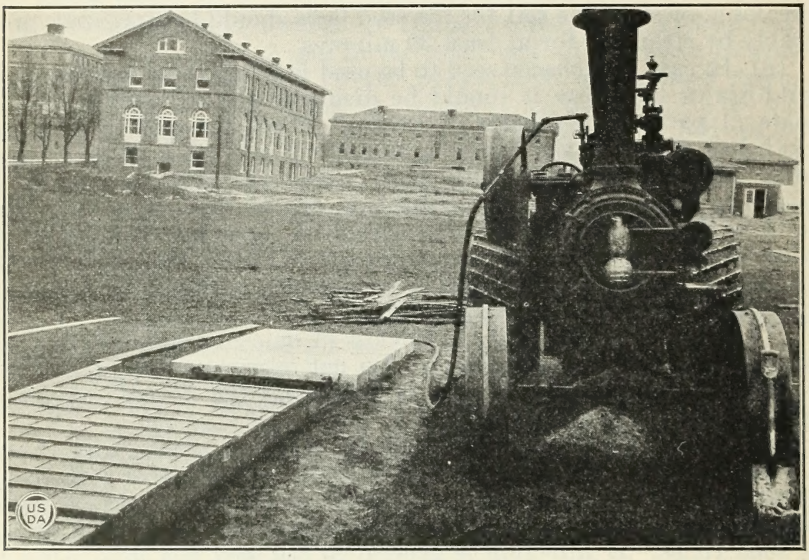


FIG. 2.—Steaming tobacco seed beds. This method is now widely used to prevent plant-bed diseases, and it is also beneficial in other ways.

pan, but it should be so placed that the steam is not thrown directly into the soil.

Soil steaming is usually done in the spring, some time before sowing the seed, although fall steaming is sometimes practiced with good results, especially where some protection can be given to the beds to prevent reinfestation with parasites and weed seeds.

The seed beds should be made practically ready for sowing before sterilization. The soil should be fairly loose, not too dry nor too wet, when steamed. The length of time required to sterilize the soil will depend largely upon its condition, especially with reference to moisture content and compactness, but ordinarily 30 minutes of steaming suffices. The cost of steaming is usually between 1 and 1½ cents per square foot.

Surface firing consists simply in burning brush or other material on the surface of the seed bed for a period of 30 to 60 minutes. The

roasting process consists in principle of shoveling about 4 inches of the seed-bed surface soil upon an iron pan under which a fire is maintained and heating it sufficiently to convert most of the moisture to steam before replacing the soil.

For the formaldehyde-drench method use 1 gallon of formaldehyde to 50 gallons of water, sprinkling this over the beds at the rate of about 50 gallons to every 100 to 150 square feet of seed-bed surface and regulating the flow so as to allow the solution to soak into the soil to a depth of at least 4 inches. The soil must then be given several days to dry out and all fumes of formaldehyde allowed to disappear before sowing the seed. For this reason the formaldehyde method is quite unsatisfactory unless its application can be made a considerable time before the time of sowing, since weather unfavorable for

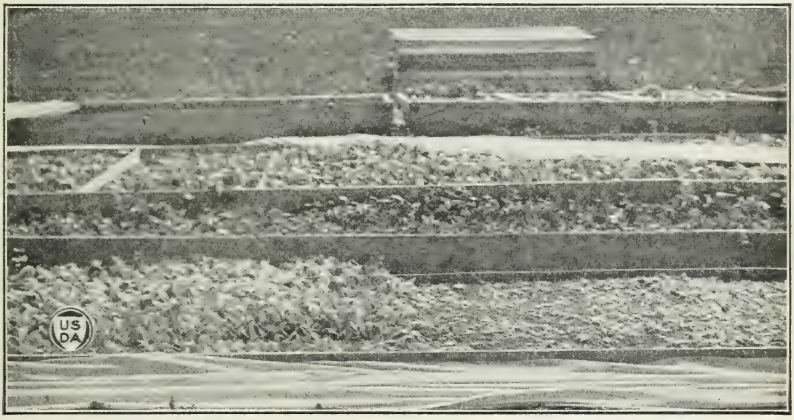


FIG. 3.—Growth of plants on soil steamed and not steamed. The area to the left of center was steamed; the area to the right was not steamed. Steamed soil produces healthy plants.

drying may delay sowing. Fall applications of the formaldehyde drench, however, may sometimes be used to advantage.

In the following pages the parasitic diseases are roughly grouped according to the parts of the plant primarily affected. The nonparasitic diseases and those due to saprophytes are in separate groups.

STEM OR STALK DISEASES.

DAMPING-OFF OR BED-ROT.

Description.—A rot of young plants starting in the stem of the plant near the soil surface in plant beds is usually referred to as damping-off. This disease may appear at almost any stage of growth of the seedlings in the bed, and, as will be pointed out later, a very similar condition may be met with on isolated plants in the field. Usually, however, the disease is most likely to occur when the plants become much crowded and the ventilation at the surface of the soil is very poor during periods of wet weather. Under such conditions the disease spreads rather rapidly, ordinarily in circular areas from isolated centers of infection. The plants generally topple over, the whole stem and leaves becoming decayed, although in other cases

only brownish or black lesions appear on the stem of the plant (fig. 4). In case of an attack of damping-off when the plants are very young the symptoms above described are not very evident, and the first indication of disease may be a poor and uneven stand of yellowish plants.

Cause.—Damping-off may be caused by one or more of several plant parasites. The most common organisms causing this disease are, however, two fungi, *Pythium debaryanum* and *Rhizoctonia solani* (*Corticium vagum*). The symptoms produced by these organisms are essentially identical, but the organisms themselves are readily distinguishable under the microscope. Both of these fungi

FIG. 4.—Tobacco plants affected with damping-off, or bed-rot. This disease is characterized by a decay of the stems of young plants in the plant beds.

are very common soil-inhabitating organisms and attack a large variety of other plants. They are most likely to be found in garden soils or other soils where their common host plants have previously been grown. They are apparently least likely to be present in soils where only grasses or grains have been recently grown. Both organisms overwinter in the soil. They do not spread as readily as many other parasites, since spores are not ordinarily produced as abundantly, nor are they so readily spread through the air.

Conditions favoring the disease.—Soils or plants remaining wet for relatively long periods furnish conditions especially favorable for the spread of the disease. High humidity around the plants as a

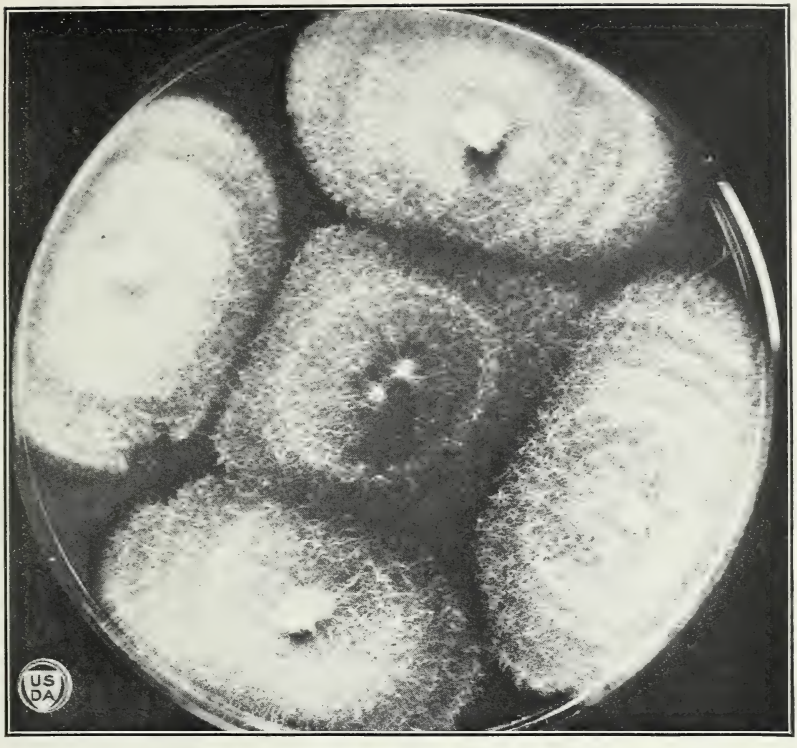


FIG. 1.—A PARASITIC FUNGUS GROWING FROM PIECES OF TOBACCO STALKS

Most plant diseases are caused by organisms of this type

FIG. 2.—BACTERIA FROM DISEASED TOBACCO

Many of the diseases of tobacco are caused by these extremely small organisms, visible only when greatly enlarged under the microscope

FIG. 1.—STEM-ROT OF TOBACCO STALK

This type of stalk injury is produced by the fungus *Sclerotium rolfsii*. (Courtesy of Wolf)

FIG. 2.—POTASH STARVATION

Curling and puckering of the leaf, with yellowish blotches, indicate a deficiency of potash in the soil

consequence of atmospheric conditions or poor ventilation in covered beds is also a predisposing factor. High temperatures are also favorable for the development of Pythium, although Rhizoctonia is apparently favored by relatively lower temperatures. Generally speaking, the thicker the stand of plants the more favorable the conditions for the spread of damping-off.

Control.—Seed beds should not be located where danger of damping-off exists unless the soil is well sterilized. Ordinarily, damping-off can be avoided by locating the seed beds on grassland or where only grains or corn have been grown the preceding year, unless the parasites are introduced with the animal manures used. Garden soils, old plant beds, weedy patches, or areas where refuse has been thrown are likely to be infested. Well-drained sandy soils are best, since they permit more rapid drying out after wet weather. Avoid the common error of seeding too thickly. Water the beds thoroughly rather than frequently, and if damping-off appears permit them to become well dried off if possible. Ventilate the beds by removing the covers during favorable weather. If the disease occurs only in isolated small areas remove the infected plants and those immediately surrounding, and if the plants are still young apply a formaldehyde solution (1 part to 50 parts of water) to the infested area, leaving off sash covers of such areas, however, to permit the escape of the gas.

The occasional occurrence of damping-off in steam-sterilized beds may result either from insufficient heating of the soil or from reinfestation due to unsterilized soil being accidentally transferred to the seed bed.

Plants showing lesions of damping-off on the stem should not be transplanted to the field, since such plants may subsequently rot off.

SORE-SHIN, STEM-ROT.

Description.—The sore-shin type of disease has been reported from various parts of the country under different names. In addition to those given, sore-shank, canker, black-leg, collar-rot, bed-rot, or damping-off may be considered synonymous as far as symptoms are concerned. As a matter of fact, however, it has not been found that these diseases are all one and the same, and it is not improbable that at least three or more different causal organisms are concerned in their production.

As the names imply, this disease is characteristically a rot, normally located on the stem or stalk of the plant and usually starting in the vicinity of the soil surface. This decay may appear only as a blackening of the surface of the stalk, but more commonly it penetrates to the woody portion in the case of large plants or completely through the stem in young plants. Under favorable conditions the blackening may extend up the stalk of the plant for a considerable distance and enter the midrib and veins of the leaves, causing them to drop (fig. 5). Affected plants are usually dwarfed and yellowish in color, owing to interference with the transfer of water and plant food. The weakening of the plant at the soil surface also renders it quite likely to be broken off at that point by the wind. If the disease does not encircle the entire stem the plant may partially or

wholly recover under conditions which are unfavorable for the disease.

Cause.—The similarity of this disease to bed-rot, or damping-off, previously described, is evident, excepting that the former rot is characteristically located in the plant beds, whereas the disease now under consideration occurs under field conditions. It seems to be fairly well established that the diseases are identical and that often the field disease arises from the transplanting of infected seedlings, although the causal organisms concerned are common soil organisms and infection from field soil is not improbable. The disease has been reported from different sections as due to *Rhizoctonia solani* and *Pythium debaryanum*, both common damping-off fungi, and to undescribed bacteria. Stem-rot, caused by *Sclerotium rolfsii* (*Sclerotinia* sp.), falls into this group of diseases as far as general symptoms, origin, and control are concerned (Pl. II, fig. 1). This disease is frequently characterized by the production of small sclerotial bodies on the surface of the diseased area. A number of other cultivated plants are affected in a similar way by Rhizoctonia in particular.

FIG. 5.—Sore-shin, or black-leg. The rotting of the stalk at the surface of the ground is characteristic. Sometimes the decay extends a considerable distance up the stalk and into the leaves.

Conditions favoring the disease.—It is believed that most cases of sore-shin are a result of transplanting plants more or less affected with the damping-off disease in the plant beds. This primary lesion may make little or no development for weeks after transplanting, but finally, under favorable weather conditions and especially when

the soil remains wet for a considerable time, the parasite may again obtain a foothold and make a fairly rapid development, with accompanying decay of the plant, before being again checked by unfavorable conditions.

Control.—The control of this disease naturally centers around the use of disease-free seedlings for transplanting. When pulling plants all those infected should be discarded. Soil sterilization and other measures should be used to prevent damping-off in the seed beds where sore-shin is of common occurrence. The disease is not usually evident sufficiently early to permit replanting. Since wet, poorly drained soils favor the disease, they should be avoided if possible, and fields frequently giving a high percentage of the disease may be advantageously rotated.

BLACK-SHANK.

Description.—A serious disease of tobacco which has long been known in Sumatra and Java as "lanasziekte" or "bibitziekte" is now said to be found in the shade-growing sections of Florida and Georgia. This disease may attack the plants in the seed beds, causing a rot similar to damping-off. It is in the field, however, that the greatest damage is done. The symptoms may be a general wilting of the plant, following marked signs of decay at the base of the stalk and extending upwards as far as 24 inches. In this respect it resembles to some extent severe cases of sore-shin previously described, but it more often resembles Granville wilt. The rot may also extend into the pith and roots of the plant. This disease also attacks the leaves, producing large brown blotches, especially after rains. The loss may frequently be very severe, involving most or all the plants in the field (Pl. III, fig. 1). The introduction and spread of this disease into tobacco districts of this country should be guarded against.

Cause.—In Java and Sumatra considerable work has been done upon this disease. It has been shown to be due to a fungus which has been named *Phytophthora nicotianae.* Experiments in this country indicate that the same fungus is concerned. This parasite is closely related to the fungus causing our common potato late-blight, which produces a serious disease of potatoes under favorable conditions for its development. The mycelium and spores of the fungus may be spread in various ways, and apparently in the case of tobacco they may persist in the soil for at least two years.

Conditions favoring the disease.—Aside from wet or humid weather little is known concerning the conditions favoring the disease. It is not unlikely that high temperatures are also favorable. Varieties and strains differ markedly in susceptibility.

Control.—Seed-bed sanitary measures heretofore described (p. 4) are important. Plants showing signs of this disease, of course, should not be transplanted, and infected seed-bed areas should be sterilized or avoided. When fields have once become infested it is unsafe to plant them to tobacco again. Especial care should be taken to prevent the transfer of infested soil from the diseased areas to new fields, by men, animals, tools, or other equipment. If the disease should become annually serious in any section the development of disease-resistant strains offers a promising method of control.

HOLLOW-STALK.

Description.—Hollow-stalk is a fairly common disease in most tobacco districts, but it is rarely important, usually occurring only on a few isolated plants. This disease is referred to in some of the oldest literature on tobacco culture, in which it is usually attributed to water-logging of the soil. The disease is characterized by the decay of the pith of the stalk in particular. It most commonly occurs on full-grown plants, where the entire pith may be rotted out, leaving the stalk hollow (figs. 6 and 7). Quite frequently the symptoms appear in the leaves, as indicated by wilting only, but occasionally the actual rot extends into the veins of the leaf. The rot may start either from the base or from the top of the stalk, but usually through wounds produced either by insects, by accidental breaking of the leaf, or by the topping or suckering operations.

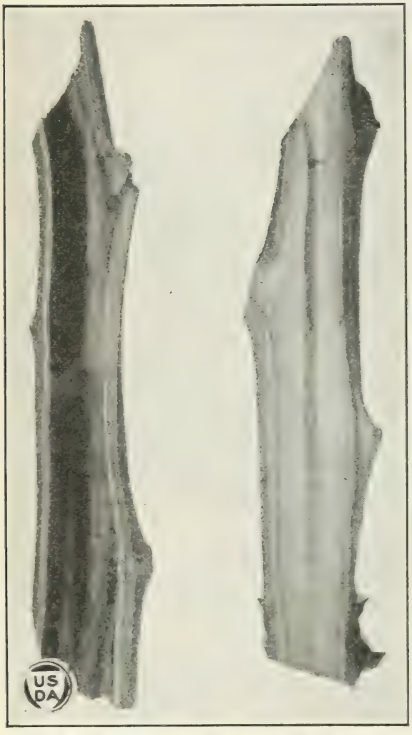


FIG. 6.—Section of a stalk of a tobacco plant (at left), showing the complete destruction of the pith by hollow-stalk. Compare with the section of a healthy stalk shown at the right.

Cause.—Hollow-stalk has been shown to be due to the invasion of bacteria of the common soft-rot type which produce decays in many vegetables, especially in carrots and cabbages, during storage. While the organism causing hollow-stalk has not been carefully studied, it is similar to the soft-rot organism in the common characters, and the soft-rot organism from carrots will produce the decay of tobacco pith. Hollow-stalk is therefore attributed to *Bacillus carotovorus.*

Conditions favoring the disease.—Wet or poorly drained soils no doubt favor infection, and continued wet weather favors both infection and rapid growth, which in turn would produce a succulent pith. Relatively high temperatures accompanying such moist weather also favor the disease. When plants are topped or suckered during such periods of weather, exceptionally favorable conditions for infection through the wounds produced occur before they can heal sufficiently. While only a very few isolated plants affected with hollow-stalk occur before topping, the disease is commonly spread to many neighboring plants in topping and suckering, the infective material being carried on the hands of workers from one plant to another.

Control.—The only measure of control which is ordinarily worth while practicing in the case of hollow-stalk is to take precautions against spreading the disease from plant to plant during topping and suckering. This is best done by leaving the topping and sucker-

ing of diseased plants until all healthy plants have been handled. If decayed pith is touched by the worker's hands they should be cleaned before continuing work on healthy plants.

GRANVILLE WILT.

Description.—This disease was first found in Granville County, N. C., and is therefore commonly referred to as Granville wilt, although it is often referred to simply as tobacco wilt. It is also known to occur in tobacco districts of Virginia, Florida, and Georgia as well as in foreign countries. Although the disease has been a serious one for a long time, particularly in North Carolina, it has not and probably never will become so in the more northern tobacco districts, on account of the fact that it thrives well only under relatively high temperature conditions. The disease has made a considerable though not a rapid spread in the southern districts. Fields ordinarily become gradually infested, so that under repeated cropping to tobacco practically complete crop failure results.

FIG. 7.—Hollow-stalk of tobacco produced by inoculation. If the bacteria causing this disease are inserted into a stalk they cause a rot, as shown in this split stalk.

The plants ordinarily are first infected through the roots from infested soil. Subsequently the disease affects the stems and leaves. Usually the symptoms first appear two to four weeks after transplanting, the number of wilting plants gradually increasing. The first characteristic sign of the disease on a plant is the drooping of one or more leaves, followed by distortion or wrinkling, yellowing, and finally browning and drying up (fig. 8). If the tobacco stalk is cut across in an early stage of the disease, the woody portion will show yellowed streaks, which in later stages turn to brown or black as contrasted with the normal white tissue. In late stages of the disease parts or all of the surface of the stalk turn black and the pith also rots out, accompanied by a decaying root system. The cut ends of the stalks or midribs when pressed yield a dirty white ooze, which is characteristic and aids in distinguishing it from certain other wilt diseases.

Cause.—Granville wilt is a bacterial disease, and the organism concerned has been named *Bacterium solanacearum*. This parasite causes similar destructive rots of tomatoes and potatoes, being capable also of attacking many other plants. The bacteria pass through and multiply particularly in the woody vessels of the plants, thereby clogging or otherwise injuring these vessels, so that the water and food supplies are cut off and the plant naturally wilts and gradually dies.

The germs live over winter in the soil or in the decaying roots and refuse of preceding crops for at least four or five years. In the yearly presence of tobacco or any other plant on which the bacteria can live the disease, of course, continues to infest the soil indefinitely instead of gradually dying out. The organism may be spread from field to field in various ways like any other soil-infesting parasite, but its spread is more frequent through direct transfer of soil from infested fields, as carried by men, animals, water, tools, or other equip-

FIG. 8.—A field of tobacco plants affected with Granville wilt. The symptoms shown here, accompanied by blackening in the woody layer of the stalk, which yields an ooze on pressure of the cut end, are typical of this disease.

ment, and these facts should be borne in mind when new land is being used for tobacco.

Conditions favoring the disease.—Granville wilt seems to be especially favored by hot weather. Dry weather usually exaggerates the disease symptoms, in that it hastens the drying up of the plants; but as a matter of fact wet weather and wet soils are more favorable for actual disease development. Sandy soils are apparently more likely to become heavily infested than clay soils. Wounding of the roots markedly favors infection, and a certain amount of this is unavoidable in transplanting and cultivating. Nematodes, which cause the root-knot disease, are common in the wilt-infested districts, and it seems that wounding of roots by these organisms greatly favors infection by the wilt organism.

Control.—The control of this important disease in the badly infested area lies in crop rotation. A number of other methods of control have been tried, among them resistant varieties and various

soil treatments, but none applicable to practical conditions has proved satisfactory.

Badly infested fields should be cropped for at least five years with crops not attacked by wilt, before replanting to tobacco. Four-year and three-year periods of cropping may suffice on land not too heavily infested. A second crop of tobacco in succession on infested soil is almost certain to result in failure. The wilt disease attacks tomatoes, potatoes, peanuts, peppers, eggplants, velvet beans, and garden beans. These crops therefore should not be grown in rotation with tobacco on infested ground. Ragweed, jimson weed, and certain other weeds are also attacked and should be carefully controlled on infested land intended for tobacco. Such crops as corn, wheat, rye (as a cover crop), sweet potatoes, cowpeas, grasses, red and crimson clover, and cotton may be safely used in rotation on infested land. General sanitary measures should also be used, aiming especially to prevent plant-bed infection by giving due regard to the location of beds with reference to infested fields and the

FIG. 9.—Fusarium wilt of tobacco. This disease resembles Granville wilt in many respects. Pressure on the cut ends of stalks does not yield an ooze.

sterilization of seed-bed soil. The use of tobacco stalks or stems as fertilizer should be avoided.

FUSARIUM WILT.

Description.—This recently described disease of tobacco was first definitely noted in Maryland, but it has also been found in Ohio, Kentucky, and Tennessee. The disease does not seem to be of common occurrence even in these districts, although in a few isolated cases as much as 20 per cent of the plants in a field was destroyed. The disease is a typical wilt and has been called Fusarium wilt (naming it from the causal organism) to distinguish it from the ordinary tobacco or Granville wilt previously described.

The general symptoms of this disease are much like those of Granville wilt, except that on cutting and pressing the infected stalk no slimy ooze is extruded from the vessels, as is common in the case of Granville wilt. Fusarium wilt may first become evident upon very young or upon mature plants. Under field conditions it is probable that infection occurs soon after transplanting, but that marked symptoms may be delayed for several weeks. In large plants the

earliest symptom is a wilting of one or more leaves of the plant, often characteristically localized on one side of the leaf or plant (figs. 9 and 10). Yellowing, browning, and drying up of the infected leaves follow, and in severe cases the entire plant is killed. Roots, stalk, midrib, and veins, as well as suckers, may become infected, as indicated by cutting across these parts even in early stages of the disease.

Cause.—This wilt disease is due to a fungus which belongs to the large group of Fusariums, rather common fungi, members of the same group producing similar but not identical diseases in various other plants. The particular species concerned with tobacco wilt has been named *Fusarium oxysporum* var. *nicotianae*. The strands of this fungus exist in abundance in the vessels of infected plants and are responsible for the wilting. The organism lives over winter in the soil and may possibly exist there in the absence of tobacco for three years. Infection, therefore, takes place from the soil, and as far as known only through wounds on the roots or basal portion of the plant.

FIG. 10.—Fusarium wilt of tobacco. Quite commonly this disease is localized and in the early stages affects only the leaves on one side of the plant.

Conditions favoring the disease.—Fusarium wilt appears to be most common in relatively warm seasons, when the soil temperatures remain as high as 80° to 90° F. for some time. Infection can occur, however, only on certain especially susceptible strains or varieties, among which White Burley and Maryland Broadleaf are most susceptible, cigar types of tobacco being generally very resistant to infection. The extent of infestation in the soil, as well as the amount of wounding, together with rainfall, naturally also plays an important part in the severity of the disease.

FIG. 1.—BLACK-SHANK OF TOBACCO

A disease of tobacco new in this country, at present limited to the Florida-Georgia district. (Courtesy of W. B. Tisdale)

FIG. 2.—LIGHTNING INJURY TO TOBACCO

Plants on the border of spots in the field damaged by lightning usually show peculiar distortions and markings

BLACK ROOT-ROT ON TOBACCO SEEDLINGS

Diseased plants not only grow slowly in the beds but if transplanted to the field often fail to grow properly

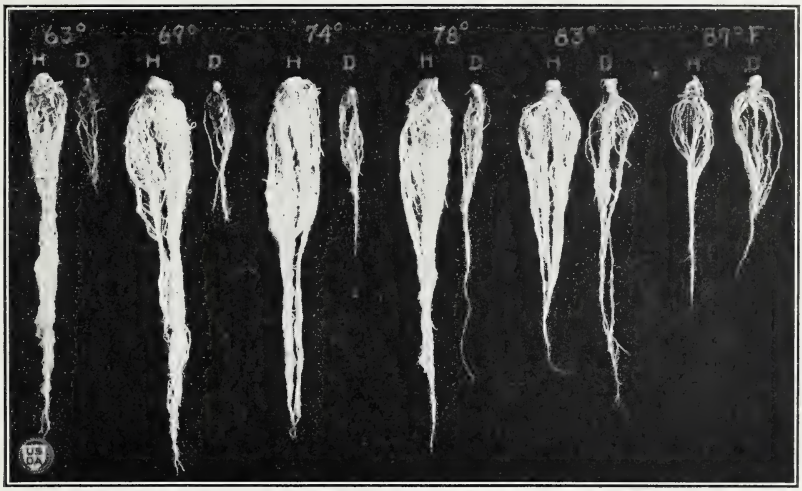


FIG. 1.—ROOTS OF TOBACCO PLANTS GROWN AT VARIOUS TEMPERATURES ON SOILS FREE FROM AND SOILS INFESTED WITH ROOT-ROT

A comparison of the growth in healthy (*H*) and diseased (*D*) soil shows that cold soils favor root-rot

FIG. 2.—LESIONS OF BROWN ROOT-ROT

Roots of tobacco and tomato plants, showing characteristic decayed areas

FIG. 1.—TOBACCO PLANT RECOVERED FROM ROOT-ROT

A heavily diseased plant like the one to the right was set into warm soil, and new roots were sent out, as shown at the left

FIG. 2.—ROOT SYSTEM REDUCED BY BROWN ROOT-ROT

In addition to browning the roots this disease completely destroys large parts of the root system, as shown by the tobacco plant at the left. The plant shown at the right possesses a normal root system

Control.—Where Fusarium wilt threatens to become serious, growers are advised not to grow tobacco on the infested soil for at least three years. So far as definitely known, this particular parasite does not attack any other plants. It is so similar, however, to the potato Fusarium wilt that, as a matter of general precaution, it is not advisable to grow potatoes in rotation with tobacco on

FIG. 11.—A tobacco plant stunted by black root-rot. A healthy root system is shown at the right.

infested soils. Precautions should also be taken to prevent the spread of the disease to uninfested fields through the use of infected plants for transplanting or the transfer of soil. A hopeful means of control, should conditions warrant it, lies in the development of disease-resistant strains within the various susceptible varieties.

ROOT DISEASES.

BLACK ROOT-ROT.

Description.—Black root-rot is one of the most widespread diseases of tobacco and undoubtedly has caused more losses to tobacco growers as a whole than any other disease with which they have to contend. This disease frequently appears in the seed bed to a serious extent (Pl. IV), but the most important damage occurs in the fields through reduced yield and poor quality of tobacco.

The disease proper is limited to the root system and the base of the stem below the surface of the soil. The roots are distinctly rotted and usually distinctly black in parts, but in severe cases the marked absence of roots as a result of the disease is especially noticeable (fig. 11). This depletion of the root system, together with the diseased condition of the remaining roots, naturally results in the starvation of the plant from lack of food and water. The symptoms on the aboveground parts of the plant are, therefore, only marked stunting of growth, usually with a yellowish or chlorotic appearance, commonly with premature budding out. Such symptoms

FIG. 12.—A field of tobacco varieties, showing differences in susceptibility to black root rot. Many varieties of tobacco are very susceptible to the disease, as illustrated by these alternate rows of ordinary White Burley, which have made little growth in comparison with the resistant types in neighboring rows.

are not ordinarily distinguishable from those produced by low soil fertility, lack of soil moisture, and certain other unfavorable conditions for plant growth, or in some instances symptoms produced by other parasites. Examination of the root system must therefore be made to determine with certainty the presence of the disease. The importance of this similarity of symptoms lies also in the fact that, more often than not, low soil fertility or dry weather has been held responsible for stunted crops where black root-rot or other plant parasites have been the actual cause of the conditions existing.

It frequently happens, however, in the case of crops infested with black root-rot that a very uneven growth develops. This condition may result either from different degrees of infection on the seedlings when transplanted or inherent differences in the resistance of individual plants to the disease where impure seed is used. Less striking unevenness may result also as a consequence of the uneven distribution of the parasite concerned or from irregular environmental conditions favorable for infection existing in the soil. Very uneven

growth of tobacco does not ordinarily result from unfavorable soil or weather conditions alone, and consequently such fields commonly indicate the presence of root-rot or in some cases other parasites.

The rapid recovery of stunted tobacco following a change in weather conditions is also characteristic of root-rot. Infested soils do not ordinarily favor a gradual and continuous growth throughout the season, but are affected by short periods of drought and cool as compared with warm weather followed by rains, so that the development of the crop occurs in short intervals rather than as uninterrupted growth.

The extent of the damage from black root-rot ranges from complete crop failures to imperceptible losses even in the presence of considerable evidence of the parasite on the roots, the latter condition resulting from the power of the tobacco plant to recover from injury to the root system. More commonly the reduction in yield varies between 25 and 50 per cent.

FIG. 13.—Field showing the growth of susceptible and resistant strains of White Burley tobacco with respect to black root-rot. The ordinary strains of White Burley (left side) failed to grow where the resistant strain (right side) made a normal crop.

Cause.—Black root-rot is caused by the fungus *Thielavia basicola.* This parasite is also capable of attacking a considerable number of other plants, usually, however, to a lesser degree than tobacco. Varieties of tobacco differ markedly in their susceptibility to the disease. This fungus produces in great abundance three kinds of spores upon the roots. The presence of one of these forms, the chlamydospores, is responsible for the jet-black appearance of some of the infected roots.

Thielavia is capable of living over from year to year in the soil and may, in fact, persist for several years even in the absence of the culture of its common host plants. This parasite does not readily spread from field to field except through the transfer of infested soil or the transplanting of infected plants. With continuous culture of tobacco most soils become heavily infested with Thielavia. The extent of the damage from this fungus depends upon the extent of soil infestation, the susceptibility of the variety grown, and the environmental conditions to which it is exposed in the soil.

Conditions favoring the disease.—Low soil temperatures during the growing season are especially favorable to serious damage from black root-rot (Pl. V, fig. 1). Since such temperatures are most likely to occur in the early part of the growing season it is at this time that

the effects of the disease are most evident. Periods of warm weather following, which are usually accompanied by dry conditions, exaggerate the stunting but permit new roots to grow out into warm, dry soil without decay, hence permitting a rapid recuperation of growth as soon as sufficient soil moisture is supplied (Pl. VI, fig. 1). Occasionally, however, a season as a whole is relatively cool, and crops remain stunted throughout the season on infested soils. On the other hand, during exceptionally warm seasons excellent crops may be produced on heavily infested soils.

The injury from black root-rot will, of course, also vary with a number of other factors of an environmental nature in the soil, some of which are not fully understood. It is certain that highly acid soils tend to reduce the disease and that soils alkaline or moderately acid in reaction or soils made less acid by the application of lime are more likely to favor the disease. Again, there is some evidence to show that more damage from the disease occurs on soils which are compact than in the same soils kept loose. Within ordinary limits the amount of water in the soil does not seem to affect materially the extent of the disease, though poorly drained wet soils may favor disease largely because of their lower temperature.

Control.—Black root-rot can be adequately prevented in the seed beds by selecting land for beds which has not been in tobacco or tobacco beds for several years. If such a change of seed-bed soil can not be made, soil sterilization, preferably steam sterilization, should be resorted to. Do not transplant infected plants to the field, since such plants will not only fail to start growth properly but in case of planting on new tobacco land serve as a source of introduction of the parasite, which will affect later tobacco crops grown on the land.

The most evident way of avoiding black root-rot in the field is by repeatedly changing the land for the tobacco crop, since continuous culture favors root-rot, whereas soils not planted to tobacco for 5 to 10 years are generally relatively free from the parasite. The frequency with which this change of land should be made, however, will depend largely upon the susceptibility to the disease of the variety grown, the time of introduction, and the rate of the increase of the parasite in the soil. Land may become too heavily infested for Burley tobacco in one or two years, whereas certain fields in the Connecticut Valley, where shade-grown Cuban or Broadleaf are grown, frequently permit continuous culture, although in certain seasons high percentages of damage from Thielavia occur.

No recommendations for crop rotation with tobacco which will safely meet all conditions can be given. Not only do the above-described factors vary the case, but the actual rest period from tobacco which is required and the crops to be grown in rotation in ordinary farm practice vary in the different growing districts. As a general principle, however, heavily infested soils should be rested four to eight years and should not be cropped in the meantime to other good host plants of Thielavia, such as beans, cowpeas, or soybeans. Corn, small grains, and most truck crops are immune to the disease.

Another means of control, which can not yet be used to its fullest advantage, lies in the use of disease-resistant varieties or strains (fig. 12). The representative types of tobacco now grown in the

United States show very marked differences in resistance to the disease. White Burley, Maryland Broadleaf, Orinoco, Pryor, and Big Cuban are susceptible. Havana Seed types and Pennsylvania Broadleaf are of intermediate resistance, and Connecticut Broadleaf, Connecticut shade-grown Cuban, Little Dutch, and other types are quite resistant.

A large number of subvarieties or strains may be similarly classified, and certain strains of types now growing in some districts are sufficiently resistant to warrant their general use provided their quality is otherwise equally desirable. The testing of the numerous strains on this basis and the development of new resistant strains for the various districts will undoubtedly greatly reduce the damage from this disease, although much experimental work remains to be done before the general usefulness of this measure will be recognized. Up to this time the development of special resistant strains with sufficient quality to be grown commercially has only been accomplished with Wisconsin Cigar Binder and White Burley types (fig. 13), although much still remains to be done even with these.

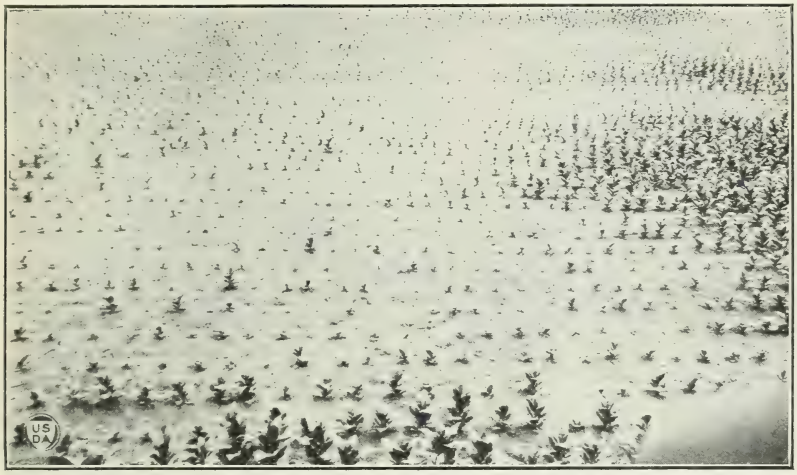


FIG. 14.—Tobacco field affected with brown root-rot. A stunted and uneven growth over the field results from this disease.

BROWN ROOT-ROT.

Description.—Brown root-rot is new to tobacco growers, in that it has not been previously described, but it has undoubtedly existed for many years, particularly in the Connecticut Valley. Brown root-rot is also suspected of occurring in Maryland, Tennessee, North Carolina, and Wisconsin. This disease should not be confused with black root-rot. The general aboveground symptoms are the same (fig. 14), and the roots are rotted as in black root-rot (Pl. V, fig. 2), but the two diseases arise from different causes, and therefore the control measures differ in some respects. The signs of the two diseases on the root are quite different, black root-rot usually showing many distinctly black roots, whereas in brown root-rot no blackening occurs. Microscopical examination of black root-rot shows the pres-

ence of spores of *Thielavia basicola*, whereas these are absent in brown root-rot cases unless the two diseases occur together. The stunting of crops as a result of brown root-rot is of course frequently laid to unfavorable conditions of the soil or to weather conditions, but repeated experiments have shown that some parasite is probably concerned.

Cause.—The cause of brown root-rot is not yet definitely established. If soils producing this disease are sterilized with heat or formaldehyde, the disease is completely controlled. This, together with other facts, practically demonstrates that some organism is the cause of this disease. Species of fungi, especially Fusarium, Rhizoctonia, and Actinomyces, as well as other fungi and bacteria, are commonly present in the diseased roots, but none of these has yet been definitely shown to be primarily concerned with the production of the disease. This same disease attacks a large number of other plants, such as tomatoes, potatoes, and other closely related plants, as well as many leguminous plants. The relation of the disease to grasses and grains is not yet fully understood. The disease is common on sod land the first year to tobacco, however, indicating that the cause may have some connection with such crops. The causal agent persists in the soil from year to year, although it seems that under unfavorable conditions, such as excessive drying or absence of host plants, it may die out with relative rapidity.

Conditions favoring the disease.—Conditions favoring this disease are much the same as for black root-rot; that is, primarily, relatively cool weather (Pl. VI, fig. 2). Dry hot weather tends to exaggerate the symptoms of the disease in the aboveground parts of the plant, but rains following such a period permit considerable recovery.

Control.—The losses from this disease are as far as known greatest in the Connecticut Valley. The high cost of production of shade-grown and other primed tobacco especially tends to make even low percentages of reduction in yield an important consideration. On the other hand, the tendency of crops to recover or land to "come back" from this disease naturally induces growers to take risks more often in planting infested fields. The experimental evidence on the relation of the crop-rotation system to this disease is as yet incomplete. Drying or aeration of the soil is favorable to its recovery from this trouble.

There seems to be no difference in varietal resistance to brown root-rot.

ROOT-KNOT.

Description.—The root-knot disease is sometimes known as root-gall or big-root. This malady is quite common in the Southern States on various plants, including tobacco, but it is practically unknown in the Northern States. The disease proper is confined to the root system. The aboveground symptoms of the disease are stunting or dwarfing of the plant, accompanied by wilting, especially in dry hot weather. These signs of the disease are consequently very similar to injury produced by other root diseases or by excessively dry weather. If the plants are pulled out of the ground, however, the roots will be found to be more or less enlarged

or swollen in sections, presenting a very irregular appearance in size and shape (fig. 15). This deformity is produced by the activity of the parasite concerned and results both in lessened feeding area of the root system as well as interference with the proper transfer of water and food to the plant. The number, size, and extent of the development of the enlargements on the roots will usually be proportional to the extent of infestation in the soil and other conditions favorable to the disease.

Cause.—Root-knot is caused by nematodes, or eelworms, which are very small animals, often barely visible to the naked eye, fairly abundant in nature. Fortunately, only a few species are commonly parasitic on plants. The common root-knot disease is due to the nematode *Heterodera radicicola.* The tissue of the roots attacked by this parasite becomes stimulated to excessive growth in diameter,

FIG. 15.—Root-knot of tobacco. The enlarged roots produced by nematodes are typical of this disease.

thus causing the enlargements. This nematode also attacks a large number of other plants, but corn, grains, and grasses as a class are not susceptible; neither are peanuts, sorghum, velvetbeans, or resistant cowpeas (Iron or Brabham).

The organism lives over in the soil from year to year and can apparently survive for at least three years, even in the absence of its host plants. It can, of course, be spread from field to field in the same manner as any other soil-infesting parasite.

Conditions favoring the disease.—Root-knot is usually most serious in light sandy soils. Heavy, clayey, or marshy soils are not favorable to its existence. High soil temperatures are favorable to its development, and overwintering in soil seems to be dependent on mild weather, such as exists in the more southern States. Moist soils are more favorable for the development and parasitism of the nematode than excessively dry or wet soils. Soils low in fertility appear to be more seriously affected than soils properly fertilized.

Control.—The only satisfactory way of controlling root-knot is by crop rotation, using crops not attacked by the nematodes between the tobacco crops. Cropping with corn, wheat, oats, rye, peanuts, sorghum, velvetbeans, or Iron or Brabham cowpeas for three years usually suffices to rid the land of nematodes if weeds acting as host plants are kept down to a reasonable extent. Precautions should be taken, of course, to prevent seed-bed infection through the soil as a harboring agent.

BROOM RAPE.

Description.—Broom rape is a fairly large flowering plant, devoid of leaves or green coloring matter (chlorophyll), which is capable of parasitic growth upon tobacco and other plants. Lacking chlorophyll, it is wholly incapable of manufacturing plant tissues

FIG. 16.—Earlier stages of development of broom rape on tobacco. This parasitic plant attaches itself to the roots of tobacco, feeding upon them and consequently producing damage in case of heavy infestation.

from the elements of the soil, water, and air and can exist only by attachment to certain other green plants from which it draws its nourishment, much like fungi and bacteria. It therefore resembles in its behavior in many respects the well-known dodders. The broom-rape seeds germinate in the soil, and the young plants attach themselves to the roots of the tobacco plants and grow to a size as large as 18 inches in length, often in very thick clumps of white, yellow, brown, or purplish stems arising from the ground to some height at the base of infected plants (figs. 16 and 17). These stems produce flowers and seeds, the latter being very small, but once in the soil they are capable of remaining dormant for long periods, subsequently germinating and attacking susceptible crop plants.

Just how much damage broom rape may do to tobacco in lowered yield and production is not fully understood. In many cases heavy infection with broom rape apparently has not done much harm. In other cases, however, stunting of infected plants is apparently

marked. As far as known, broom rape is largely limited to Kentucky tobacco fields, especially in the White Burley district, although it has been known to occur on tobacco in other States. The infested area seems to be limited to the hemp-growing district, the same broom rape being also parasitic on hemp. The seeds are commonly mixed with hemp seed and are sown with it; hence they infest the soil upon which tobacco is subsequently planted.

A large number of species of broom rape are known, especially in foreign countries. The common species in the Kentucky fields is *Orobanche ramosa*. Aside from tobacco, this species also attacks hemp, tomato, potato, rape, cabbage, and parsnip; but corn, cereals, grasses, and legumes as a class are immune to this species. The control of the trouble, therefore, is largely based on crop rotation, using plants not susceptible to attack on infested land for several years before replanting to tobacco or other crops, where such precautions are deemed necessary.

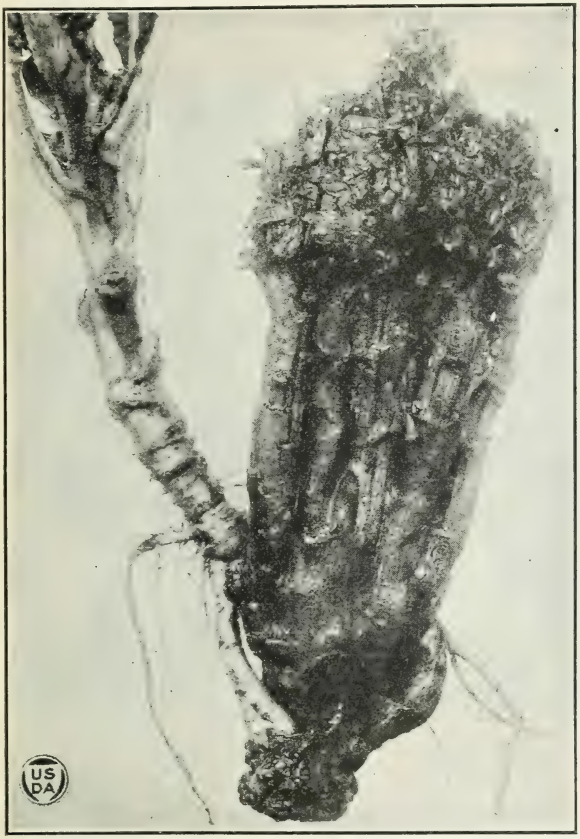


FIG. 17.—Later stages of development of broom rape on tobacco.

LEAF DISEASES.

WILD-FIRE.

Description.—A serious outbreak of an apparently new disease which became known as wild-fire occurred in North Carolina in 1917. This disease has since become introduced into practically all tobacco districts. The occurrence of wild-fire is more or less sporadic, being markedly influenced by weather conditions, but the seriousness of the disease, under conditions favorable for its spread, is well established by the large losses which it has caused since its recognition.

Wild-fire may attack plants at almost any stage of growth, and so far as is definitely known all field infection originates from infected seed beds. The most typical symptoms in the plant bed as well as in the field are on the leaves in the form of spots which are

usually circular, of a bleached or yellowish color (chlorotic area or halo), and often as large as a dime (Pl. VII, fig. 1). In the center of each spot is a dried area often only the size of a pin point, but varying in size up to as much as half an inch in diameter. The chlorotic area may consequently be only a narrow border or entirely lacking, depending upon the age of the spot and other conditions. These spots when numerous may run together, forming irregular areas and sometimes causing the whole leaf to collapse and dry up. In other cases the bleached or chlorotic area may spread into and throughout an entire leaf, apparently from a center of infection in or near the bud or stem of the plant. Such plants usually fail to make satisfactory growth.

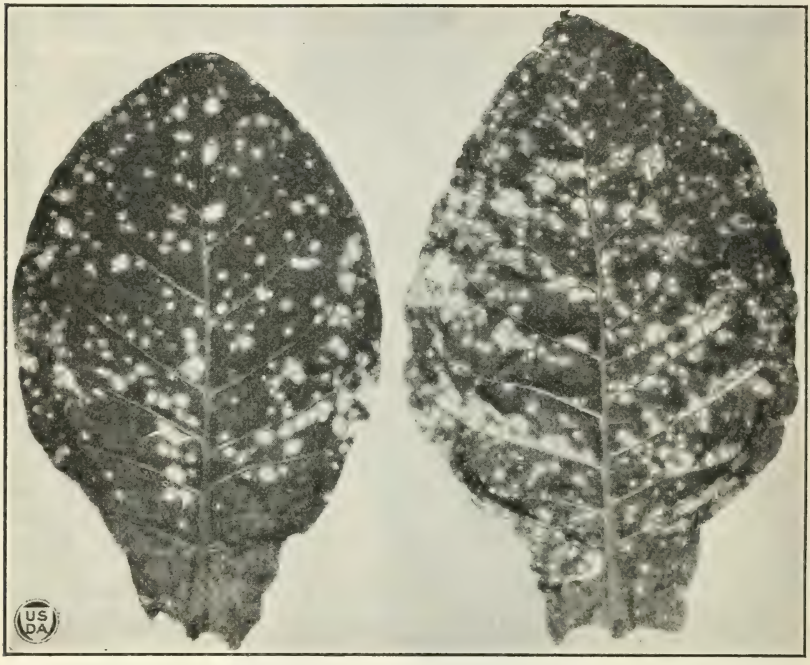


FIG. 18.—Tobacco leaves showing wild-fire. Affected leaves finally become more or less ragged and may often be made practically worthless.

The bottom leaves are most likely to become heavily infected, not only because they are exposed to infection for a longer period of time but also because they are in a more favorable environmental position for infection (fig. 18). Under favorable conditions for infection, however, the disease may spread to the uppermost leaves on the plant and even to suckers and seed pods. Cigar wrapper and binder tobaccos especially may be rendered worthless for the purposes for which they are used by a comparatively few infections per leaf, while other types may not be seriously damaged unless the spots are sufficiently numerous to markedly affect the color of the leaf or cause such extensive drying up in the field as to render harvesting impossible without much breaking, thereby lowering the yield and producing a ragged crop.

In many districts mild cases of wild-fire are likely to be mistaken for rust or firing of a less serious kind. Many other forms of leaf spots or rust occur, as will be described later, but with close observation the grower, in most cases, can learn to distinguish wild-fire from other diseases. When found it behooves the grower to use all possible precautions to prevent its further spread.

Cause.—Wild-fire is caused by an organism belonging to the bacterial group and known as *Bacterium tabacum*. This organism is capable of entering tobacco leaves, especially through wounds, and when once started proceeds to multiply to enormous numbers, so that hundreds of thousands of bacteria eventually may be present in a single spot and serve as a source of infection on the same or other leaves as soon as conditions become favorable.

Under unfavorable conditions for the growth of the bacteria, however, they are usually short lived. While the great majority of them die during the season without producing any infection, a few manage in some way to live over winter and become the source of seed-bed infection the next season. Under just what conditions and on what materials used in or about seed beds the bacteria overwinter is not yet definitely known in all cases. While strong suspicion rests on dried leaves, seed, soil, seed-bed covers, and so forth, yet all observed cases can not be explained on these grounds. Nevertheless, our present basis of control must rest on the supposition that some of the bacteria do in some manner live over winter on one or more of the materials or equipment used in growing plants. It now seems, however, that tobacco trash from infected crops, transferred in some manner to seed beds in the spring, is the most likely source of infection.

Once infection has occurred in the seed bed or field, subsequent spread is readily explained. In addition to being spread through the air by rain and wind, it may be carried by men, animals, tools, or any other equipment in various ways from leaf to leaf, plant to plant, and farm to farm unless proper precautions are observed.

Conditions favoring the disease.—Beating rainstorms are well known to be especially favorable to the spread of wild-fire in the fields or in unprotected seed beds. This follows from the fact that such storms not only spread broadcast the organisms causing the disease, but also wound the leaves sufficiently to markedly aid infection, at the same time furnishing the necessary moisture. Few new infections occur during dry weather, although heavy dews remaining on the leaves for some time permit some infection. To wound the leaf tissue is not necessary for infection in all cases, but it enhances infection markedly. Rainy periods without accompanying winds may result therefore in a very considerable spread of the disease. As far as temperature is concerned, wild-fire seems to work over a wide range, although some difference occurs in the incubation period and the type of injury produced. Some infection will take place with the temperature as low as 60°, but the best infection results when it ranges between 80° and 90° F.

It is also fairly evident that rapidly growing tobacco, as a rule, is more likely to become heavily infected than stunted tobacco. It also seems that some relation exists between the type of soil or the fertilizer applied and the extent of infection, but this relation is not yet fully understood.

Control.—The control measures recommended are largely concerned with the production of disease-free plants in the seed beds. Failing in this, healthy plants should be sought elsewhere in preference to taking the chance of introducing even a seemingly small amount of infection into the field.

The principles of plant-bed sanitation previously stated (p. 4) apply particularly to wild-fire prevention. In addition to this, it may be necessary to resort to other methods. In districts where wild-fire is almost certain to be of general occurrence and the probability of obtaining completely disease-free plants seems small, it may be advisable to spray or dust the seed beds with Bordeaux mixture once or twice a week to hold down the amount of infection.

Where wild-fire infection is found in isolated spots in the seed beds, destroy the plants in such areas, together with surrounding plants, by burying or applying formaldehyde (1 part to 25 parts of water) and covering the treated area to hold the fumes. The covers should not be replaced on the treated beds until most of the formaldehyde fumes have escaped into the air; otherwise the healthy plants may be damaged. The disease may be easily spread throughout the bed from such infected areas during the process of weeding beds or pulling plants for transplanting.

If wild-fire develops in the field on only a few isolated plants early in the season it is well to destroy them and replant with healthy plants. In case of a high percentage of infection, it is often advisable to plow up and replant the entire field if the season is not too far advanced. If such a procedure can not be profitably attempted owing to lateness of the season, serious effort should be made to remove all the infected leaves as thoroughly as possible early in the season with the hope that such reduction of infective material, together with the chances of an unfavorable season for the disease, may hold its spread down to a minimum.

With persistent effort on the part of the grower to hold down the disease and to destroy or otherwise dispose of all infected material on the farm, including the plowing down of sucker growth in the fall before it becomes infected, much headway will be made toward reducing the chances of wild-fire in the crop the following year.

BLACK-FIRE.

Description.—A tobacco leaf-spot which has probably been existent for many decades, especially in Virginia and other southern districts, but which has not been carefully studied until recently, is the disease now properly referred to as black-fire (angular leaf-spot). The disease is in many respects similar to wild-fire, occurring in the same districts, and doubtless the two are often confused by growers. Since these diseases are caused by different parasites, though similar, and as the symptoms of the two are fairly distinct, they must be considered separately, although the control measures for both diseases are much the same. It may likely develop that from a practical standpoint the chief reason for the grower recognizing the difference between these and other leaf spots lies in the fact that one or the other of such diseases will prove much more dangerous in some sections than others, which will influence the control measures undertaken. So far as known, black-

fire is more or less confined to the Southern States, whereas wild-fire seems likely to be a serious disease in the Northern States as well as in the South. In 1920 black-fire is said to have been especially serious in Virginia and was found in 85 per cent of the fields inspected, causing an estimated loss of more than $5,000,000.

In the seed bed the black-fire leaf spots are quite small, angular in shape, and black or dark brown in color, with a narrow, clear border especially distinct when held up to the light (Pl. VIII, fig. 1). The spots on seedling leaves always remain small and do not approach the size attained in the field. When a considerable number of infections occur the leaf often becomes deformed and ragged.

In the field young black-fire spots in the early stages are much like those in the seed bed, but later they become as large as half an inch in diameter. On thin leaves the spots are usually quite angular in outline, whereas on thicker leaves they are more rounded, sometimes zonated, from tan to dark brown, sometimes almost black in color (Pl. VIII, fig. 2). The conspicuous bleached border or halo so characteristic of wild-fire is absent, although some yellowing occurs around the spot.

Cause.—Black-fire is caused by a bacterium which has been named *Bacterium angulatum*. This organism closely resembles the wild-fire bacterium in appearance and behavior. So far as known the overwintering and spread of this organism is practically the same as that of wild-fire.

Conditions favoring the disease.—As in the case of wild-fire, frequent rainfall and especially rain with strong wind is favorable to infection and spread of the disease. Good and well-balanced fertilization appears to favor the occurrence of infection rather than poor fertilization, which results in less rapid and succulent growth. Low topping, as compared with high topping, has been found to favor the disease. Low topping is, however, usually essential to the production of proper size and body of leaf, especially in the dark export types of tobacco.

Control.—Seed-bed sanitation measures, as described earlier (p. 4), and general precautions as recommended for wild-fire control (p. 28) apply equally well to black-fire. There seems to be definite evidence that in the case of black-fire the germs may live over from year to year on seed and on cloth covers, and special attention should be paid therefore to seed disinfection and the use of new cloth covers or to the sterilization of old covers every season. As an aid to the production of disease-free seed, it is advised that seed pods showing no sign of infection should be selected. To cover flower stalks with paper bags will aid in protecting pods against infection. Seed 2 or more years old is quite unlikely to carry infection, but in all doubtful cases these precautions should be supplemented by seed disinfection. The plowing under of stubble as soon as the tobacco is harvested is recommended for infected fields, especially if tobacco is to follow on the same land.

THE WISCONSIN LEAF-SPOT.

Description.—Two bacterial leaf-spot diseases have already been described, namely, wild-fire and black-fire. The Wisconsin leaf-spot is a third form of bacterial disease, causing similar but not identical

symptoms. As far as known, it is rarely as serious as the two above-mentioned diseases. This leaf-spot is undoubtedly the so-called ordinary "rust" of Wisconsin, but on account of the fact that practically all leaf-spots, regardless of actual cause, are commonly referred to as "rust" by growers, the term "Wisconsin leaf-spot," for want of a better name, is used at present to distinguish it from other rust spots. So far as known, this disease is limited to Wisconsin, where it is fairly common in some years, but occurs only rarely to a damaging extent.

The disease is in many respects similar to wild-fire, as far as symptoms are concerned, except that these are less pronounced (Pl. VII, fig. 2). The bleached area or halo surrounding the center of infection is usually much narrower than that characteristic of wild-fire spots. However, wild-fire spots also often appear without marked halos surrounding them, and these are almost identical with the Wisconsin leaf-spot. In such cases it is necessary usually to resort to laboratory methods to distinguish the two. This can be done readily, since wild-fire is caused by a white bacterium, whereas a yellow bacterium causes Wisconsin leaf-spot.

Wisconsin leaf-spot also makes its first appearance in the seed beds, where the spots resemble those of black-fire in that they are usually quite small and more or less angular. In the field the disease is usually confined to the bottom leaves, only under exceptionally favorable conditions spreading as high upon the plant as wild-fire or black-fire.

Cause.—Wisconsin leaf-spot is caused by an organism which has been named *Bacterium melleum*. Aside from its yellow or honeylike appearance on some culture media, it resembles the wild-fire and black-fire organisms closely in shape and size. Wounding is especially favorable for infection. The spread and overwintering of the organism are most probably the same as for wild-fire.

Conditions favoring the disease.—The occurrence of the disease in the seed bed has usually followed protracted periods of wet weather. Its occurrence in the field is also dependent upon rainy weather, or at least moisture and high humidity on and surrounding the leaves. Storms no doubt favor the disease by spreading the germs and wounding the leaves.

Control.—Very little experimental work has been done aiming at the control of this disease in particular. Where control measures need to be practiced the same measures that were described for wild-fire control will apply.

FROG-EYE.

Description.—This leaf-spot disease of tobacco is fairly common, though not often serious, in the southern tobacco-growing districts, but as far as known it is rare or does not occur in the northern districts. The term "frog-eye" is unquestionably applied to various leaf-spots similar in appearance but arising from different causes. The description here applied, however, refers to one particular disease ordinarily recognized in literature as properly called frog-eye because of the presence of the particular causal organism concerned. This leaf-spot is characteristically located on the bottom leaves of the plant, especially toward their maturity. More or less circular brownish spots, with a grayish white area in the center, upon which

commonly very small dark specks (spores) can be seen, are typical of the disease. Considerable variation in the shape, size, color, and relative size of the colored areas occurs, however, and correct diagnosis of the disease is dependent upon the occurrence of the spores of the causal organism on the spot (Pl. IX, fig. 1). The diseased spots ordinarily do not break and fall out of the leaf in dry or cured tobacco. While the disease is not usually regarded as serious and in fact may be regarded as desirable in mild form, yet in isolated cases the damage from it is reported by individual growers to be relatively very high.

Cause.—The frog-eye disease of tobacco has not been carefully studied, but sufficient work has been done to show that it is caused by the fungus *Cercospora nicotianae*, to which it has long been attributed. The long, narrow, septate spores appear in small bunches on the surface of the central area of the spot and can readily be seen with a small hand magnifying lens. Practically nothing is known about the overwintering and spread of this particular disease, but from closely related diseases we know there is nothing unusual in overwintering in the spore form and subsequent dissemination from primary infections by wind and rain.

Conditions favoring the disease.—Moisture is essential for the germination of the spores and subsequent leaf infection. Frog-eye is especially likely to develop or spread following long periods of rainy or damp weather, or even following heavy dews, which remain on the basal leaves for long periods in the case of large tobacco. Mature leaves appear to be more susceptible than unripe leaves, but no particular difference in varietal susceptibility seems to have been observed in this country.

Control.—Practically nothing is known about satisfactory means of controlling this disease, and since it occurs infrequently to a serious extent no effort, so far as known, has been attempted in that direction. While it seems likely that the soil may be the common or only source of infection in the spring, this is not established with certainty. Until this fact is established recommendations for control practices can not be satisfactorily made. Where the disease occurs on primed tobacco, something can be done in the case of heavy outbreaks by attempting to keep ahead of the disease by harvesting, but this is practicable, of course, to only a limited extent.

BLUE-MOLD.

Description.—In March, 1921, there appeared in the seed beds of the shade-growing district of Gadsden County, Fla., and Decatur County, Ga., a disease not previously found on tobacco in this country. This disease proved to be one commonly called "blue-mold" in Australia and Malaysia, where it had often appeared as a more or less serious trouble of tobacco. The disease spread very rapidly in the seed beds in the Florida-Georgia section and for a time seemed to threaten the industry, but fortunately it disappeared rapidly, doing little or no damage in the field, owing, possibly, to a change in weather conditions. The disease did not reappear in 1922, although judging from the experience of other countries, it is not unlikely that it may reappear at any time to a more harmful extent.

The signs of the disease are especially distinctive in one respect, namely, in the appearance of the white to light-purple or bluish mildew, which is usually found on the lower surface of the leaf. The leaf tissue is broken down by the mildew and subsequently turns brown and dries up in patches of irregular size and shape, frequently limited by the veins of the leaf (Pl. IX, fig. 2). In severe cases the seed bed as a whole has a patchy and scalded appearance. Only the leaves appear to be attacked.

Cause.—Blue-mold is caused by a fungus belonging to the group of downy mildews, some of which are well-known parasites on other crops. The tobacco mildew is known as *Peronospora hyoscyami*, having been first found on black nightshade, a plant related to tobacco. The fungus produces spores in great numbers. These are powdery and light and easily carried by the wind through the beds, which accounts for its rapid spread through beds when once infected if favorable weather conditions prevail. These ordinary spores are, however, very short lived, although other longer lived spores may be produced under certain conditions and carry the fungus over unfavorable periods, thus accounting for its overwintering when this occurs.

Conditions favoring the disease.—Parasites of this class are usually very sensitive to environmental conditions and consequently are quite sporadic in their occurrence. Moist warm weather and sometimes alternating cool nights and warm days are most favorable for infection. In the Florida-Georgia section the outbreak was seemingly associated with several days of heavy dew and fog in the mornings. With the cessation of these dews and fogs the disease became less conspicuous and finally disappeared entirely.

Control.—As soon as signs of this disease appear in a seed bed the plants in the infected area, together with the surrounding bordering plants, should be destroyed at once, preferably by applying formaldehyde solution (1 to 25). This should be followed up by burning over or other means of eradication. All the bed should then be sprayed daily with Bordeaux mixture (2–2–50) in an attempt to hold the disease in check, destroying with formaldehyde solution any new infection which may appear.

In the event of failure to control the disease in the seed bed it is inadvisable to transplant diseased plants to the fields if it is at all possible to obtain healthy plants elsewhere. Although the disease appears to be primarily a seed-bed trouble, it is not unlikely that it may prove equally serious in the field, weather conditions being favorable. In case of repeated occurrences of the disease, general seed-bed and field sanitary measures, such as have been previously described, should be undertaken, but until more experience with the disease is had in this country, further recommendations can not be given with any certainty as to their value.

OTHER PARASITIC LEAF-SPOT DISEASES.

Although a considerable number of other parasitic leaf-spot diseases are reported from foreign countries, they do not seem to occur in this country.

In the early nineties three different fungi were reported as causing different leaf spots in North Carolina. A "brown rust" concentri-

FIG. 1.—WILD-FIRE FROM PLANT BEDS

Transplanting should not be done from infested beds if it is at all possible to get plants from healthy beds

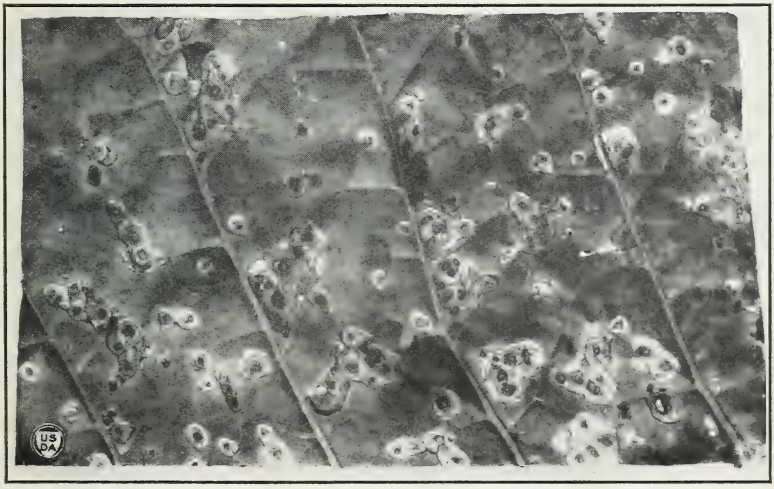


FIG. 2.—A BACTERIAL LEAF-SPOT

This disease is rarely serious and so far as known is practically limited to Wisconsin. It is easily confused with wild-fire in some cases

FIG. 1.—BLACK-FIRE FROM SEED BEDS

The spots are not ordinarily as conspicuous as wild-fire spots. (Courtesy of F. A. Wolf)

FIG. 2.—BLACK-FIRE FROM FIELD

The spots are more angular than those of wild-fire and they do not have the conspicuous halo usually associated with wild-fire. (Courtesy of F. D. Fromme)

FIG. 1.—FROG-EYE OF TOBACCO

Not all of these young spots are typical, but the presence of the spores of Cercospora is a sure indication of the disease

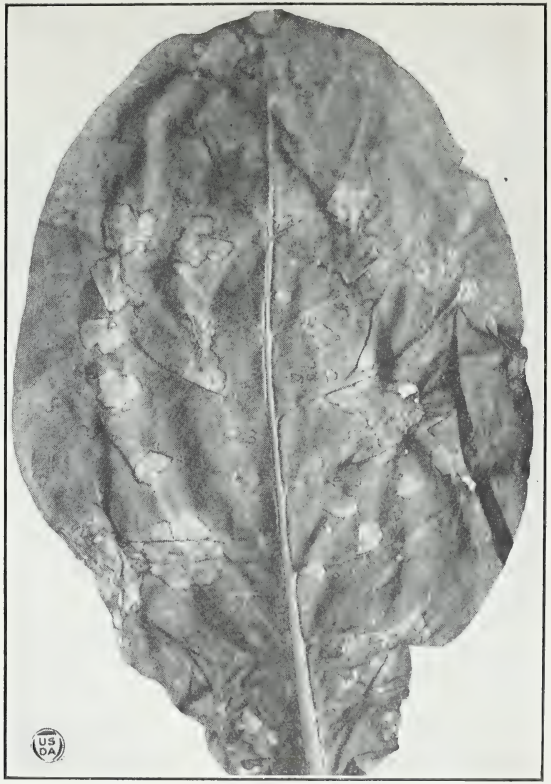


FIG. 2.—BLUE-MOLD OF TOBACCO

Irregular blotches of dead tissue are produced, but the presence of mildew on the underside of affected leaves is the most pronounced symptom

FIG. 1.—"FIRING" OF TOBACCO

This is characterized by a general dying back from the tips and margin of the leaf

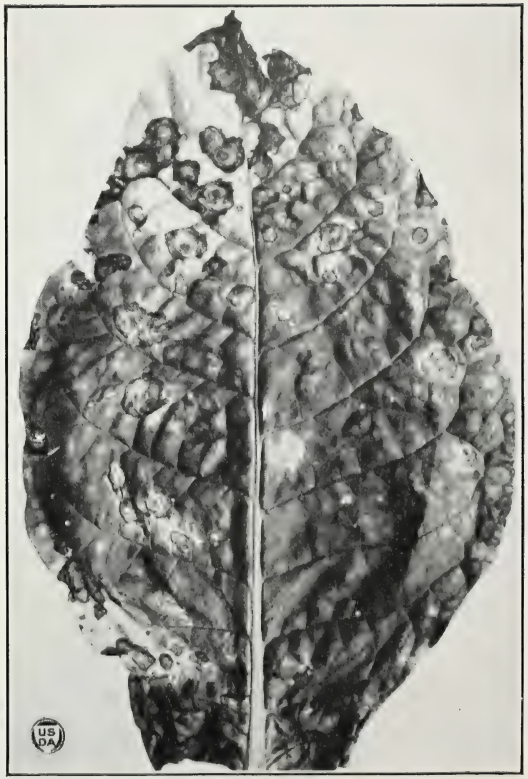
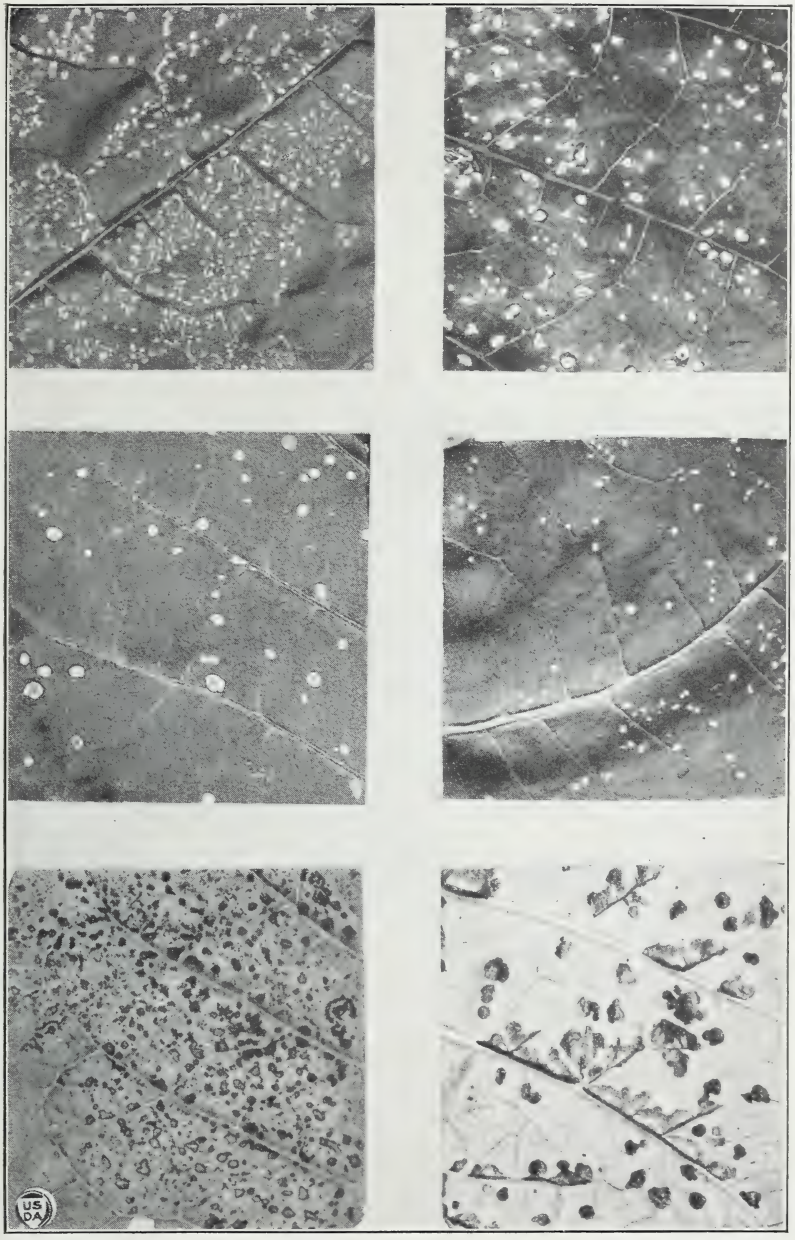


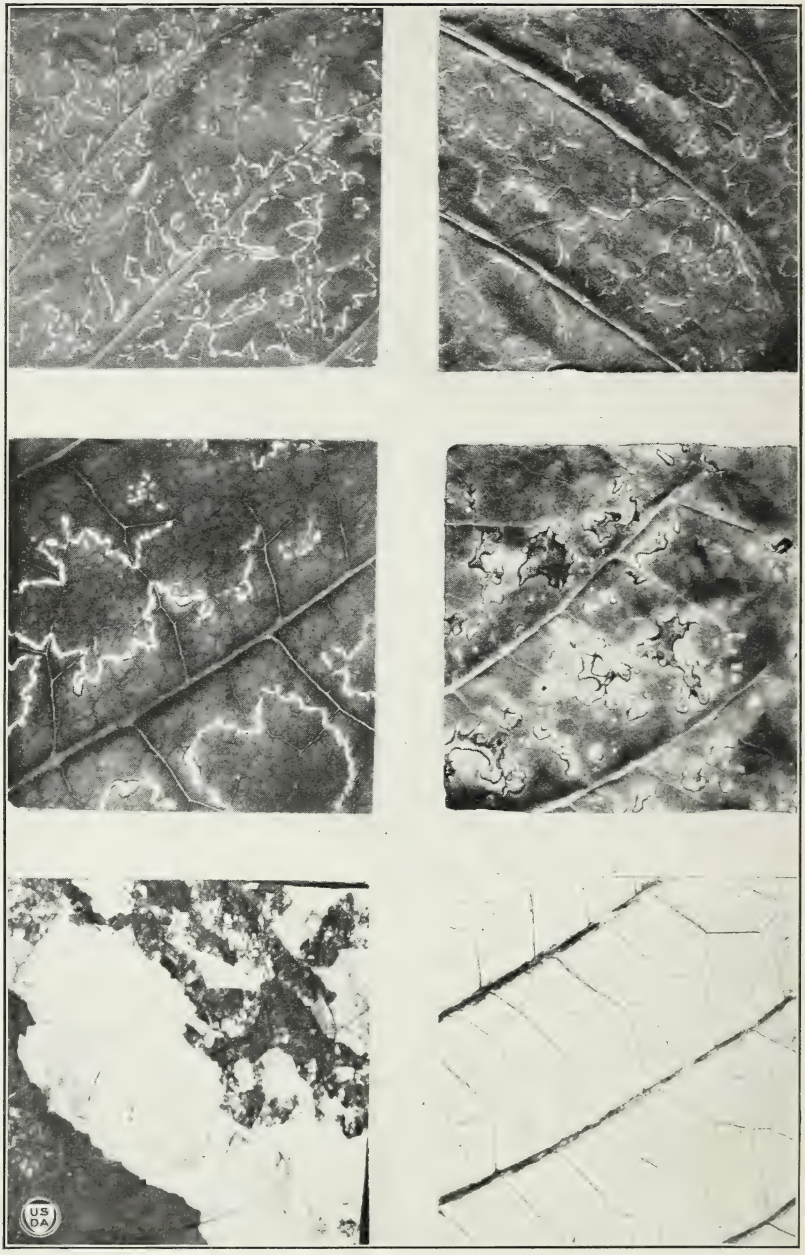
FIG. 2.—A NONPARASITIC LEAF-SPOT

Not infrequently spotting is more or less characteristic of certain varieties of tobacco on some types of soil



NONPARASITIC LEAF-SPOTS

A great variety of spots occur on tobacco leaves which are believed to be of nonparasitic origin



NONPARASITIC LEAF INJURIES

Many forms of injuries of comparatively rare occurrence show in their distribution a more or less definite relation to the position of the leaf veins

cally zonated was said to be due to *Macrosporium longipes* n. sp.: a "white-speck" disease was attributed to *Macrosporium tabacinum* n. sp.; and an irregularly shaped spot, pale dirty brown, lighter in the center, with a reddish zonate margin was attributed to *Phyllosticta nicotiana*. No mention is made of inoculation experiments, and the pathogenicity of these fungi is therefore questionable. So far as known, they have not since been described on tobacco in America, except for one recently reported occurrence of *P. nicotiana* in North Carolina and a fungus, apparently Phyllosticta, on tobacco seedlings in Virginia.

A recently reported disease which is most commonly found producing a leaf-spot in seed beds, where it may also cause damping-off, but which may also apparently appear in the field, has been found to be due to a species of Fusarium, closely resembling *Fusarium affine*. Exceptionally high moisture accompanied by some preliminary weakening of the plant due to unfavorable conditions appears to favor infection. Only isolated cases are known, and the disease is not to be regarded as an important one.

NONPARASITIC LEAF-SPOTS.

Under this general term may be included a considerable number of leaf-spots or injuries which differ considerably in appearance and are evidently due to various causes arising from the effect of soil or weather conditions on plant growth rather than following the attack of any parasitic organism. No distinct line can be drawn between this class and other abnormalities of plants resulting from malnutrition or other causes, but arbitrarily we may include those diseases in which the early symptoms are mor or less characterized by spotting of the leaves. This class of tobacco diseases has considerable historical interest, since such diseases were apparently among the earliest observed maladies of tobacco, or at least all early observed spotting was attributed to nonparasitic influences.

Such terms as "firing," "specking," "rusting," and "spotting," with various modifications usually descriptive of the color of the diseased areas, have been used from the earliest days of tobacco culture. Their origin has been laid to all sorts of causes, none of them, however, with any satisfactory proof for the theories presented. There can be no doubt that some of these diseases, such as frog-eye, black-fire, and Wisconsin leaf-spot, were early included in the list of diseases attributed to nonparasitic agents which are now known to be due to specific organisms. The belief held from the earliest time was that spotting of tobacco leaves was due to an excess or deficiency of fertilizers or water in the soil or to a succession of certain weather or atmospheric conditions. These theories are, of course, sufficiently broad so that some of them are doubtless responsible for some forms of spotting, but they are not of much help in explaining the frequently distinctive types of nonparasitic spotting which are now known to exist and that usually can not be produced at will by subjecting the plants to variations of the above-named conditions. In view of this fact, control measures for many of these forms of spotting are not at hand.

From recent observational and experimental evidence it appears that at least four main types of nonparasitic spotting exist on the basis of causal agents, namely, those due to (1) a hereditary predisposition toward spotting, (2) unbalanced nutrition, (3) absorption of toxic agents, (4) toxic agents applied externally. As illustrations of these groups the following may be cited: Under certain conditions the Sumatra and Connecticut Broadleaf varieties commonly show spots when other varieties do not. Phosphorus deficiency in the soil may result in spotting. Soils rendered toxic by sterilization or by the addition of certain salts may produce spotting of leaves. Spraying with certain insecticides or fungicides produces spotting. In all these cases, however, the weather conditions apparently affect the occurrence of these spots to a greater or lesser extent.

Attempts to classify the nonparasitic tobacco leaf-spots occurring naturally on the basis of symptoms with some consideration of their origin are not usually satisfactory. A few more or less distinctive types have been named, and the predisposing weather conditions are at least partially understood.

Firing, as most properly used now, refers to a drying up of the basal leaves, usually starting at the leaf margins and proceeding inward between the veins, in blotches rather than spots (Pl. X, fig. 1). This is conceded in most cases to result from dry weather, resulting in the starvation of the plant as a whole for food and water and the withdrawal of these from the basal leaves to supply the growing point. A more or less sudden deficiency of food alone in the soil in relatively wet weather may result similarly, especially on sandy soils artificially fertilized and subject to leaching or otherwise losing the reserve food supply. On the other hand, an excess of phosphoric acid on certain soils is said to result in firing.

The true forms of nonparasitic spotting are usually sharply demarcated, round to angular in shape, varying from a considerable size to mere specks (Pl. X, fig. 2) and from almost black to white in color (Pl. XI). Others exist more or less as continuous lines or circles showing marked relation to the veins (Pl. XII).

Dead blotches in tobacco leaves sometimes follow after distinct symptoms of specific malnutrition have existed for some time, as in the case of potash and magnesium starvation, but these will be given separate consideration, as they are not regarded as typical leaf-spot troubles.

Leaf spotting sometimes results from physical causes, such as bruising by rain, hail, or wind.

The control of the main forms of nonparasitic spotting is for the present limited to avoiding varieties or strains, where possible, which are predisposed to this injury, maintaining a proper balance of fertilizers in the soil, or avoiding the use of soils which are not ameable to fertilizer treatment.

THE MOSAIC DISEASE.

Description.—Mosaic is one of the most common and widespread diseases of tobacco. The disease is often referred to by different names in various districts, such terms as "calico," "mottling," "gray-top," and "mongrel" being often used. "Frenching" is another term commonly applied to mosaic, but this term properly used applies to a distinct though somewhat similar disease. Mosaic is not

ordinarily feared by growers, since it often occurs without doing appreciable damage, although in some years, in certain districts particularly, the losses from the disease are very large both in yield and quality.

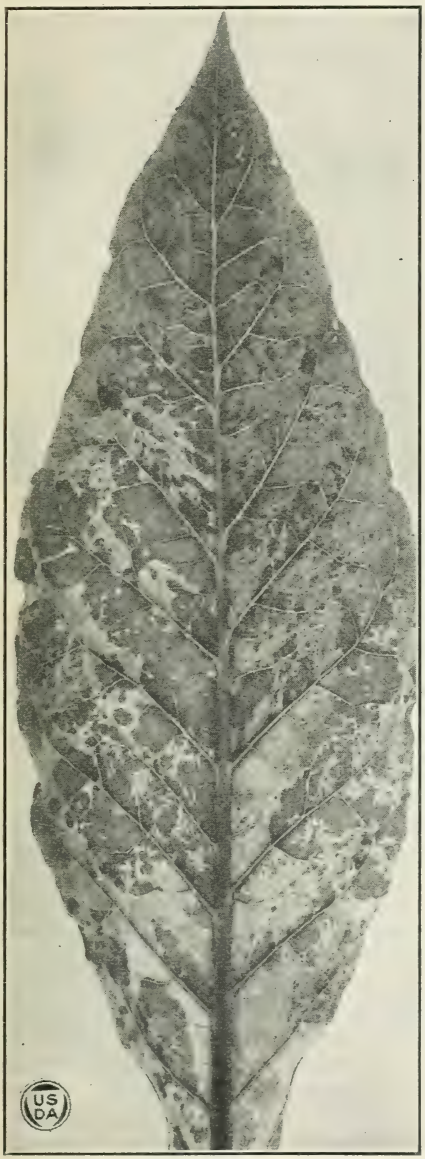


FIG. 19.—Tobacco mosaic. The mottled appearance is the most characteristic sign of this disease.

The symptoms of mosaic in tobacco are numerous, varying from only faint signs to those that are most distinct and pronounced. The most common and characteristic symptom is mottling of the leaves—that is, alternate dark green and yellowish (chlorotic) areas irregularly scattered over the leaf surface, usually being most distinctive in the top or youngest leaves, particularly in the early stages of the disease (fig. 19).

The more pronounced symptoms are blistering, curling, and distortion of the leaves, followed by dwarfing of the entire plant (Pl. XIII, fig. 1). In older plants the flowers may also become dwarfed, distorted, and bleached. Under certain weather conditions it is not uncommon for mosaic plants, even though showing only faint symptoms in the leaves, to develop more or less spotting, ordinarily referred to as "rust" or "firing," but such cases are by no means always a consequence of mosaic (Pl. XIV). On plants where the suckers show characteristic mosaic symptoms and the spotting is not due to any other evident cause, mosaic is usually responsible. The losses from mosaic follow as a consequence of the reduced yield due to dwarfing of the plants and the mottling or abnormality of the leaves, which render them unsuitable for use for certain purposes of manufacture.

Cause.—From the standpoint of science mosaic is one of the most puzzling diseases of plants. Repeated efforts to demonstrate the actual cause of this disease have so far failed. It is well known, however, that the disease is infectious, being readily transmitted from diseased to healthy plants in various ways. It practically follows

that some parasite must be concerned, which has so far escaped detection either because of its extremely small size or because of other peculiarities. Not only tobacco but a considerable number of other plants are affected with mosaic identical with or closely similar to that of tobacco. Tobacco mosaic can be transmitted to certain other plants, particularly to some belonging to the same botanical family, such as tomato and pepper. This fact is especially important, since the ability of this disease to live on other plants may account for overwintering in some cases. Experimental and observational evidence in tobacco mosaic thus far indicates that the causal agent does not live over winter in the soil or in the seed. In the case of mosaic of other plants it has been shown that the disease persists over winter in the living underground parts of perennial plants. Such a general carrying-over agent for tobacco mosaic has not yet been demonstrated. On this principle, however, weeds in and around tobacco beds should not be tolerated on farms where mosaic is to be reckoned with as a serious disease.

In this connection it should be stated here that probably all mosaic of tobacco occurring in the field originates from seed-bed infection. The signs of the disease in the bed usually are only very slightly visible, if at all, and usually occur only on isolated plants. From these plants, however, it is readily transmitted to many other plants in the operations of pulling and transplanting or by other means. The importance of preventing seed beds from becoming infected is evident. Aside from the overwintering of the parasite in perennial host plants and its subsequent transfer to plant beds, it should also be stated that under some conditions of storage of infected material it may survive for a year or more, so that overwintering on tobacco refuse, plant-bed covers, frames, or other equipments is not beyond reason.

When infection has once occurred in the spring, its spread from plant to plant may usually be accounted for. Aside from transmission during the numerous times the individual tobacco plants are handled, it is likely that insects, especially plant lice, may spread the disease under field conditions, as can be readily demonstrated experimentally.

Conditions favoring the disease.—Tobacco mosaic is dependent upon specific infection from other mosaic plants. Once inoculated, plants are almost certain to show the disease at one stage or another in their growth. Aside from the fact that weather conditions influence the length of the incubation period—that is, the length of time between inoculation and the first signs of the disease—their influence does not seem to be important as affecting the occurrence of mosaic. It is quite evident that tobacco mosaic is favored in development by relatively high temperatures (80° to 85° F.), although temperatures higher than this tend to retard its development until at about 100° F. it is no longer active, and diseased leaves tend to recover. Closely associated is the fact that rapidly growing plants tend to show the symptoms earlier and more markedly, though subsequent growth may be retarded. Rainfall and humidity do not seem to have any such direct relation to infection and progress of mosaic as to certain other leaf diseases. Where insects are important carriers of the disease, conditions affecting their occurrence and numbers appear to have a direct bearing on the occurrence of mosaic.

Control.—More facts in regard to the cause, overwintering, and dissemination of mosaic must be ascertained before control measures especially applicable to this disease can be assured. In general, however, the measures which are applicable fall under the head of seed-bed sanitation. The location of seed beds a considerable distance away from weedy patches of ground where the disease may be hibernating in perennial plants, soil sterilization to kill weed seeds or any other possible infective material in the soil, and persistent destruction of solanaceous weeds around seed beds and in other locations are recommended. Plant-bed frames or covers previously used with beds in which mosaic plants appeared should not be again used without sterilization. Special precautions should be taken to prevent the introduction into the seed bed of any trash from the preceding year's crop. Before planting, the beds should be carefully examined for mosaic plants, and even if only a very slight infection is noticeable it is advisable not to use any plants from such beds if good plants can be obtained elsewhere. Where infected plants appear to be numerous in areas of the bed, it is practically certain that a poor crop will result from transplanting from such beds. Infection may occur in the seed bed, however, without being noticeable. If it is found that the symptoms show up in the field early in the season on a large percentage of the plants, it is usually advisable to disk up and replant. No possible means of controlling the disease in the field are known. On the other hand, the disease does not ordinarily spread in the field early enough to cause any considerable damage.

FRENCHING.

Description.—The disease of tobacco commonly known as frenching occurs in practically all tobacco districts of the United States and in many foreign countries. It is often referred to under other names, such as shoestring, sword-leaves, strap-leaves, rosette, and polyphyllie. The disease is often mistaken for the mosaic disease and confused with it on account of the leaf deformities and chlorosis produced which are also characteristic of mosaic. There is no relation between the two diseases, however, from the standpoint of cause, as sometimes seems possible when the two diseases occur simultaneously on the same plant.

The symptoms of frenching vary greatly in their intensity of expression. The earliest stages of the disease, especially in very young leaves, are characterized only by a yellowish or chlorotic appearance, with some increased thickness and brittleness of leaves. As the growth of these leaves continues they will show an early tendency toward narrowness and mottling. Later, the margins of the leaves may curl downward and the younger leaves in the bud increase to abnormally high numbers, though being usually closely bunched. In later stages of the disease the leaves are frequently normal in color but extremely narrow in proportion to their length, quite thick, and ruffled at the margin (fig. 20). In the most severe cases the number of these stringy leaves becomes extraordinarily high, often reaching more than five times the normal number on the stalk, which is usually considerably shorter than normal, hence producing a distinctive rosette appearance. More commonly, however, the disease is limited to chlorosis of the top leaves. The losses from this disease

are not extremely high, although it is at times quite an important factor in crop production (fig. 21).

Cause.—The actual cause of frenching is not yet known. Although a number of predisposing factors have been observed, the production of this disease at will, as far as known, has not been repeatedly accomplished. Frenching is apparently not infectious; consequently there is no reason to believe that any foreign organism

FIG. 20.—A frenched tobacco plant. The numerous shoestringy leaves are typical. This disease is often confused with mosaic.

is associated with it. The disease is frequently found on soils exposed in one way or another to excessive water. This, together with its occurrence at times on portions of fields in poor tilth, indicates a relation to soil aeration. On the other hand, frenching seems to have considerable relation to soil fertility, or at least to a deficiency of certain fertilizing elements, but in combination with these factors certain weather conditions must apparently exist to bring about its expression.

Control.—Measures to prevent this disease are not as yet satisfactorily worked out. Land likely to yield the disease should not be used for tobacco. If such soils must be used, it is probable that proper drainage, subsoiling, and cultivation conducive to good tilth, together with well-balanced fertilization, will be very useful in preventing it.

SAND-DROWN.

Description.—A blanching or chlorosis, especially of the lower leaves of tobacco plants grown on very sandy soils during seasons of excessive rainfall, has long been known as sand-drown. This disease occurs particularly in the tobacco districts of North Carolina, but also may be found in the sandy soils of other States, as in the Connecticut Valley. This trouble is most likely to be confused with another nutritional symptom fairly common in tobacco and known

FIG. 21.—A badly frenched field of tobacco. This disease is commonly characteristic only on certain types of soil or under certain soil conditions.

as potash hunger or potash starvation. Potash hunger may occur, however, on almost any type of soil and under quite variable conditions of rainfall. The blanching in potash hunger is usually more localized in small areas, quite yellow in color, and sometimes overcast with bronze or copper colors, together with crinkling or curling of the leaves. Sand-drown is characterized, on the other hand, by more or less complete and uniform blanching until the leaf is practically white in late stages except for the midrib and veins, which retain their color (Pl. XV). The blanching usually starts at the tip of basal leaves, proceeding downward along the margin and inward between the veins toward the midribs. Crinkling and curling are not common, but occasionally local areas die out, as in the case of potash hunger or leaf-spot diseases.

Cause.—Sand-drown has recently been shown to be due to a shortage of magnesium in the soil or in the fertilizer used. Most soils

naturally contain sufficient magnesium for the plant's needs, or it is supplied in the ordinary system of fertilization practiced. On certain sandy soils low in natural fertility and supplied with artificial fertilizers containing little or no magnesium, the deficiency of this element becomes evident in seasons of considerable rainfall when the small supply of available magnesium may be leached away.

Control.—The use of so-called high-grade or relatively pure mineral commercial fertilizers, especially the high-grade potash salts, to the exclusion of low-grade forms or organic forms (originating from vegetable or animal matter) favors the appearance of sand-drown under the conditions described. The addition of sulphate or chlorid of magnesium to the fertilizer salts in relatively small quantities prevents the chlorosis. Dolomitic limestone (high in magnesium) and fertilizers of vegetable origin, as cottonseed meal, tobacco stalks and stems, and barnyard manure, tend to prevent the disease. A relatively small amount of magnesium is apparently sufficient to remedy sand-drown, even in striking cases of deficiency, less than 50 pounds per acre usually being sufficient.

POTASH STARVATION.

The lack of sufficient potash in a soil is often characteristically indicated by tobacco plants grown in such soils, especially if other fertilizing elements are not lacking. Aside from a general stunted appearance, the leaves become crinkled or rough and turn downward at the margin. Yellowing usually starts at the leaf tips, becomes most marked along the margin, but proceeds inward between the veins in blotches, without sharp demarcation. A bronze or copper tinge over parts of the leaf surface is also commonly associated with the yellowing. Smaller yellow spots may develop, which finally turn brown or grayish white, and the whole leaf may finally dry up. Specking or spotting may also be characteristically associated with these symptoms of potash hunger. Leaves deficient in potash are frequently brittle both in the green and cured condition (Pl. II, fig. 2).

If symptoms of potash starvation are noted sufficiently early, some benefit may come from a liberal application of a readily available potash salt between the rows of the growing crop. The fertilizer formula for the following year's crop should contain both some readily available and some slowly available potash.

OTHER MALNUTRITION SYMPTOMS.

A deficiency of other elements in the soil is not so characteristically indicated as in the case of potash and magnesium. The lack of nitrogen is indicated in most plants by a light-green to yellow color and stunting. This condition is brought about as well, however, by a number of other variable factors, such as deficiency or excess of water, poor tilth, or shortage of light, so that not much reliance can be placed upon it. Excess of nitrogen tends to produce a large dark-green, heavy-bodied, coarse leaf usually undesirable except in dark export types of tobacco.

In case of phosphoric-acid deficiency the plants may remain normally green or even turn darker green than ordinarily, particularly in the case of young plants. In case of marked deficiency of this ele-

ment brown leaf spots may develop (Pl. XIII, fig. 2). Marked stunting, with yellowing, may eventually follow.

Before attributing the above-described symptoms to nitrogen or phosphoric-acid starvation the roots of the plants should be carefully examined for root injury by the root parasites previously described. At the same time the weather and soil conditions in general must be taken into account. Chemical analysis of the soil may aid in determining which element is lacking, but trial application of fertilizing elements is the most reliable method to determine the fertilizer needs of any particular soil.

INJURIES DUE TO PHYSICAL AGENCIES.

The tobacco plant is subject to a number of injuries resulting from the action of physical agencies which may be grouped together. These deserve brief consideration under the subject of diseases, because they may sometimes be mistaken for plant diseases.

Injuries of this nature which frequently appear on tobacco are rain-spot, hail cuts or spots, frosted or frozen tobacco, sun-scalded

FIG. 22.—Lightning injury to tobacco. This apparently diseased area was produced by lightning striking the field.

and sunburned tobacco, wind whipping, bruises from handling, spray injury, sand beating, and lightning damage (fig. 22; Pl. III, fig. 2). To these might also be added the large group of insect injuries, some of which are sometimes mistaken for disease injury. Most injuries of the above-named types soon after taking place are ordinarily too evident to warrant description (fig. 23). Some time after the damage has occurred, however, and especially when affected leaves have been cured or fermented, considerable difference of opinion may arise as to the source of the damage found.

UNIMPORTANT OR RARE DISEASES NOT OTHERWISE CLASSIFIED.

A considerable number of abnormalities occur in rare or isolated cases in tobacco fields, regarding which little is known as to causal relations, since sufficient importance is not attached to such cases to warrant investigation. Some of these diseases have not been described at all or not more than once in the literature, so that comparisons are difficult to make.

One of the more common abnormalities of this nature is sometimes known as marbling or variegation, but in foreign countries goes un-

der a wide variety of names, panachure being especially used. This is a condition of the leaf in which large bands or irregular areas of the leaves of isolated plants lose their green color, becoming yellow or distinctly white and sharply demarcated from the green areas. This condition is not infectious, but is apparently hereditary. More rarely the entire leaf or part of the plant turns yellow or white, when it is spoken of as albinism or chlorosis.

A form of curly-dwarf is not unknown in tobacco, but is very rare in this country. In the East Indies and Europe, similar diseases are described as krulzieke and faltenzwerg. In this disease the leaves become markedly stunted and curled. The cause is unknown.

A streak disease of tobacco apparently of nonparasitic origin has been occasionally noted. A narrow brown line usually extends the

FIG. 23.—Damage to tobacco from hail and storm. Various degrees of injury result from this cause. An extreme case of injury to shade-grown tobacco is here shown.

full length of the stalk and into the leaves, following the vascular system and causing wilt and death of the affected leaves. It has been seen most commonly on White Burley tobacco.

A trouble known as crookneck has been described from North Carolina. The plants and leaves are twisted and deformed. The stem and leaves on one side of the plant are usually affected and die or fail to grow, while the growth of the other parts causes the twisting and malformation observed, much as in the case of lightning injury.

Monstrosities or teratological phenomena are sometimes observed in tobacco as in other plants (fig. 24). These are usually characterized by fasciations, as in the doubling of stalks, midribs, veins, or leaf blades, or in the splitting up of one leaf into two or more apparently distinct parts.

Crown-gall caused by *Bacterium tumefaciens*, a fairly common disease on some of the fruits, produces striking tumors on the tobacco plant by artificial inoculation. As far as known, however, this disease does not occur naturally upon tobacco.

DAMAGE IN CURING AND FERMENTATION.

The diseases of tobacco previously described have been concerned with maladies affecting the living plant and are either of a parasitic or nonparasitic origin. Following harvest, the tobacco leaves must first go through a curing process which consists essentially of a more or less rapid drying and consequently death of the leaf tissue itself. The conditions of curing, fermentation, and storage of the various types of tobacco must be such as are most conducive to the proper color, body, texture, elasticity, grain, burn, and other factors which make up quality for the individual types. Any distinctive abnormalities from the desired result in these processes are naturally of as much concern as abnormalities of the growing plant and consequently must receive attention as to cause and control measures. For the most part the damage in curing, fermentation, and storage is the result of the action of undesirable microorganisms under conditions favorable for their development. These organisms belong to the class of saprophytes rather than the parasites, since they act ordinarily on dead tissues only, in which they tend to produce decay. In this connection it is well to remember that the decay and final disappearance of all organic matter is dependent upon the action of such organisms and that any method which eliminates their presence completely, such as sterilization, or which renders conditions unfavorable for their development can be relied upon to preserve most such materials indefinitely.

FIG. 24.—Jack-in-the-pulpit effect of a leaf growth in the bud of a tobacco plant, illustrating rare phenomena of the monstrosity class.

The most common forms of damage in tobacco following harvest are shed-burn or pole-rot, stem-rot, wet-butts (or fat-stem), white veins, black-rot, must, and molds. These injuries will be taken up in the approximate order of their occurrence.

SHED-BURN OR POLE-ROT.

Description.—This damage is also known under the name of pole-burn and pole-sweat. It is characterized in mild cases by the darkening and the tendency of the leaf to dry out rapidly and to become harsh and brittle, together with loss of elastic strength. In more severe cases the body of the leaf is actually decayed, so that affected spots appear dark by reflected light but transmit light more readily

than the normal leaf. As the decay proceeds these spots run together, and the infected areas break up and fall out at the least disturbance (Pl. XVI, fig. 1). This trouble is most common in tobacco which is air cured rather than in any system of curing using more or less heat. Under favorable conditions for its occurrence large losses may result.

Cause.—It seems fairly well established that at least some of the symptoms described for shed-burn are due to microorganisms. There is not good agreement, however, as to just which organism or organisms are primarily concerned in all cases. The most recent experimental evidence seems to indicate that several fungi are capable of damaging the leaf in a similar manner. Species of Alternaria, Fusarium, Botrytis, and other fungi and bacteria are probably most instrumental in actual decay.

Conditions favoring attack.—Tobacco leaves ordinarily are not attacked by these organisms while they are still in the green or yellow stage of curing. Normally, in the air-curing process no danger of damage exists until some time after harvest, or when the leaves are turning from the yellow color to the final stage. At this stage anything that is conducive to excessively high humidity may bring about shed-burn, especially if at the same time the temperature is quite high. The ideal conditions for air curing itself are a relatively high temperature (80° to 100° F.) together with a relatively high humidity (80 to 90 per cent). When the relative humidity rises above 95 per cent, however, there is considerable danger, especially if little or no circulation of air prevails. Under such conditions little pockets of air form between closely hanging leaves and between leaves and stalks in which the actual humidity reaches saturation, the leaf surface becoming actually moist through precipitation of moisture from the air or by excretions from the leaf which are not carried off, thus producing a favorable medium for the growth of microorganisms which can enter the leaf tissue and consequently damage the leaf. It follows, therefore, that the close hanging of large tobacco or an improperly ventilated shed are conducive to shed-burn. Foggy or damp weather at the critical stage of curing, especially if it persists for several days with a moderate temperature, should be guarded against by control measures.

Control.—The principles of control of shed damage are primarily concerned with proper ventilation to secure adequate circulation of air throughout the shed or raising the temperature within the shed by artificial heat, thereby reducing the relative humidity of the air. The former is dependent upon the proper construction of the shed, together with proper management of the ventilating system.

The quantity of moisture the air can hold varies greatly with the temperature. The ratio of the amount of moisture actually in the atmosphere at any time to the amount which can exist in the air at that temperature is known as relative humidity. The capacity of the air for holding moisture is doubled for every increase of 18° to 20° F. in temperature, and consequently its relative humidity is reduced by half. Under normal conditions the temperature of the curing shed rises in the daytime and the relative humidity falls. As the temperature falls at night the relative humidity rises often above 95 per cent but again falls the following day. During rainy or foggy weather the relative humidity, of course, remains high,

FIG. 1.—LEAF MALFORMATION AS A SYMPTOM OF MOSAIC

The malformation of the leaves is not always present in mosaic, nor is it in itself a certain symptom of mosaic

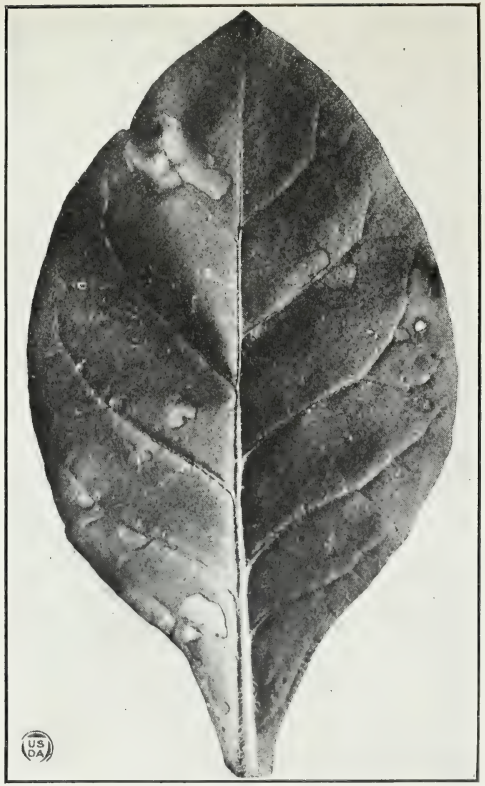


FIG. 2.—PHOSPHORUS DEFICIENCY

A very low phosphorus supply in the soil may result in spotting, as was experimentally demonstrated in this leaf

MOSAIC SOMETIMES FOLLOWED BY RUST

Leaf-spots and blotches often occur on large leaves showing little or no mosaic symptoms. The sucker leaves on such plants will usually show typical mosaic symptoms, as illustrated by the two upper small leaves in this illustration. The two small lower leaves are from healthy plants

SAND-DROWN OF TOBACCO

A low supply of magnesium in the soil causes the leaves to become chlorotic

FIG. 1.—SHED-BURN DAMAGE

Tobacco in process of curing is subject to this form of damage when the air in the barn is excessively humid as a result of weather conditions or poor ventilation

FIG. 2.—STEM-ROT AND WET-BUTTS

The decay of the midrib and portions of the stalk develops from the white fungous growth seen here. The dark portion on the leaf at the left is water-soaked, typical of wet-butts

FIG. 1.—BLACK-ROT IN FERMENTATION

The dark portion at the lower end of the hand shows black-rot. A similar hand when shaken broke up, thus showing the extent of the rot

FIG. 2.—MUST ON TOBACCO

A white powderlike growth, accompanied by a musty odor, is typical of this disease

and if this is maintained for comparatively long periods, especially in relatively warm weather, with tobacco at the danger point in curing, damage is likely to occur unless the relative humidity is lowered by raising the temperature in the shed by artificial heat.

Heat is usually applied as open fires under the tobacco. A number of small fires uniformly distributed is preferable to a few large fires. Frequently small pits are dug in the ground in which the fire is placed. Small deflectors above the fire are also desirable. Charcoal, very dry wood, or corncobs may be used, but coal or coke, or material giving dense smoke should not be used with most types of tobacco. The shed is usually tightly closed, except for roof ventilators, which may be left partly open. The length of time fires are kept up will depend on weather conditions, but usually 12 to 24 hours will be sufficient to prevent damage.

STEM-ROT OF CURING TOBACCO.

In the curing process the midribs or stems of the leaves and the large veins are usually the last to dry or cure out, owing to their thickness. Under normal conditions the moisture given off by these tissues passes off into the air immediately on reaching the surface, but if high relative humidity prevails they become soggy and are therefore a favorable medium for the growth of saprophytic microorganisms (Pl. XVI, fig. 2, *B* and *C*). This condition does not usually come about until the leaf web itself is quite fully cured out and the greatest danger from shed-burn is over. The midrib has then turned from the normal color, indicating actual death of the tissues. At times, however, the veins decay before the leaf web loses its green color. The saprophytic organisms concerned may be the same as those associated with shed-burn, although this is not fully established. Species of Fusarium, Tricothecium, Botrytis, and other fungi are at least frequently present in dense masses of white and pink growths, often followed in bad cases by bacterial decay.

Conditions favoring stem-rot and its control are the same as for shed-burn.

WET-BUTTS, OR FAT-STEM.

The term "wet-butts" refers to a wet, soggy, and discolored condition of the base of the midrib and the veins, but sometimes including the whole leaf, resulting from the failure of the leaf to cure properly (Pl. XVI, fig. 2, *A*). As far as known, no careful investigation of this trouble has been conducted, but from observation it seems possible that it is due in some cases to freezing weather before the stem is fully cured. This is borne out by the fact that it is the top leaves, generally in late green tobacco, which are usually affected in this manner. In stripping and sorting, the affected leaves are separated and allowed to dry out before being packed, when they are placed in the poorer grades of tobacco.

When a large percentage of wet-butts is likely to occur in a crop of tobacco it is a good plan to hasten curing with artificial heat before freezing weather.

WHITE VEINS.

Occasionally during curing a whitened appearance of the veins of the leaf arises, making it undesirable for cigar-wrapper pur-

poses. This condition has been attributed in some southern districts to the action of an insect (thrips) feeding on the veins of the leaf in the field, with the result that when cured these become much lighter in color than the remainder of the leaf.

In the northern districts white veins appear occasionally, apparently as a result of excessively rapid curing of the leaf during dry weather. It is believed that the surface layers of the veins, drying out more rapidly than the deeper layers of tissue, permit a thin layer of air to form between the two layers, thus causing the veins to appear white. In any case it is a good plan to keep up the humidity of the shed in dry weather by keeping the shed closed in the daytime, opening it partly at night, and occasionally applying water to the ground in the shed to raise the humidity of the inside air.

BLACK-ROT IN FERMENTATION.

Description.—Following curing, tobacco is ordinarily graded and bulked in various ways, depending upon the type, when it is sufficiently pliable for handling without breakage. Leaf tobacco of manufacturing types is usually "reordered" to bring it to the proper moisture content before storage, and damage rarely occurs. Leaf tobacco of cigar types, however, is usually allowed to come into higher "case" before being removed from the curing barn, with the result that it often contains a high percentage of moisture, and, moreover, it is not "reordered" before packing in boxes for fermentation or sweating.

Black-rot is ordinarily found, then, in boxed cigar types of tobacco. It usually appears as a dark-brown or black discoloration of the packed tobacco, which varies from only small insignificant local areas on a few leaves to almost complete ruin of the entire lot. Commonly the affected area is more or less limited to the tip ends of the leaf where they overlap in packing. The affected tissue is ordinarily characterized by a dry rot, and the body, texture, and elasticity of the leaf no longer exist, and it easily breaks up when disturbed (Pl. XVII, fig. 1). Commonly a sooty appearance is present, as a result of the production of large numbers of spores by the organism causing the decay. The line of demarcation between rotted and sound areas is frequently quite sharp, and the sound portions of the leaf are still of value for cigar purposes if large enough to warrant their separation. Sometimes black-rot appears in bundled tobacco before sorting. The loss from this trouble is frequently quite large in the packing houses of northern cigar-tobacco districts.

Cause.—Black-rot has been found to be due to a fungus common in nature, *Sterigmatocystis nigra*, more often called *Aspergillus niger*. This fungus is peculiar in that it thrives best at relatively high temperatures (around 100° F.), such as exist in fermenting tobacco. It can also grow, of course, at considerably lower and slightly higher temperatures.

The fungus produces spores abundantly, which can remain dormant for a long time, are readily carried about in the air, and are quite common in tobacco warehouses. When these spores are present on tobacco they can germinate under favorable conditions and produce decay of leaf tissue in a few days.

Conditions favoring attack.—The extent of damage from black-rot will ordinarily vary with the number and distribution of the spores of the causal organism present and the favorableness of the conditions for their development. Moisture is naturally essential for growth, and as a matter of practical importance the percentage of water present in the fermenting tobacco is the most important consideration in damage from black-rot. The high temperatures produced by fermentation, together with a relatively high moisture content of the leaf, make an especially favorable condition for black-rot to develop. It has been found that black-rot can not occur above 110° F., since the rot fungus can no longer grow above that temperature.

Control.—The control of black-rot must center around either reducing the moisture in tobacco to an amount necessary only for proper fermentation or raising the temperature of fermentation as rapidly as possible to around 110° F. or above. With the object of keeping the moisture content down, growers should be advised not to permit tobacco to come into too high case when taken down in the shed. When high-case crops are received in the warehouses they should preferably be assorted and packed as late in the sorting season as possible or bulk fermentation carried out before packing in cases. Bulk fermentation usually permits temperatures as high as 110° to 120° F. being reached in a few days, hence is unfavorable for black-rot, and the accompanying turning of the warm tobacco in the bulk is especially favorable for reducing its percentage of moisture before packing in boxes. The number of rebulkings should depend somewhat, therefore, on the amount of moisture in the tobacco, in order that it may be brought down to a desirable moisture content before being packed in storage.

The alternative of packing directly into the boxes and storing at once in room temperatures as high as 110° F. suggests itself. This method has not been satisfactorily tested, as far as known. Earlier methods of force sweating in boxes were usually at lower temperatures and not satisfactory. Finally, it is not at all improbable that cigar tobaccos may be passed through drying or "reordering" machines, which will not only reduce danger of damage but tend to produce a more uniform product in general.

MUSTS AND MOLDS.

True tobacco musts are characterized by a white powderlike growth over the surface of the leaves during fermentation or storage (Pl. XVII, fig. 2). No true decay occurs, nor is the leaf ordinarily injured in any way excepting in appearance and in aroma. A musty odor accompanies this damage, which it is practically impossible to remove satisfactorily, and consequently affected tobacco is much reduced in value. This trouble is fairly common upon fermenting or stored cigar tobaccos. It does not ordinarily seem to be associated with black-rot in the same packings, and consequently the conditions favoring the two are apparently different in one or more respects. Practical observations indicate that when certain types of tobacco lie for several weeks in boxes before going into active fermentation, mustiness is likely to appear. Similarly, mustiness may develop following fermentation in storage. Mustiness is not favored particularly by the high temperatures of fermentation nor

necessarily by high moisture content of the tobacco, although the relation of moisture is not yet fully understood. The character of the tobacco leaf itself, as regards various factors resulting from growth and method of handling, probably plays some part in its predisposition to musting. The presence of air in packed tobacco also seems to favor musting, so that loosely packed leaf seems more likely to become affected, especially if the humidity in the warehouse is high.

True musts are caused by a group of extremely small organisms of the fungous type. More than one species seem to be involved. *Oospora nicotianae* or very similar species and in some cases Actinomyces are responsible. Some of these organisms grown on tobacco or other media have an extremely musty odor.

Molds due to other fungi are also found on tobacco, but less commonly and usually only under exceptionally undesirable conditions of handling and storage. A condition sometimes mistaken for must or mold on tobacco is the excretion of a white salt (usually saltpeter) on the midrib and veins of the leaf. This is of a less harmful nature than musts or molds and is readily brushed off without injurious odors remaining. This condition apparently results when the leaves are subjected to more or less rapid drying under certain conditions. The character of the soil upon which the leaf is grown seems to influence the occurrence of saltpeter to a considerable extent, and it is more or less characteristic on tobacco of certain districts.

The prevention of musting of tobacco is not satisfactorily understood. The avoidance of conditions previously mentioned as favorable to it only can be advised. When tobacco has become musted some packers resort to brushing off the musty color, redampening the leaf with water or acetic-acid (vinegar) solution (about 4 per cent), and repacking with the hope that a second fermentation may be started and the undesirable odor partly removed.

DISEASES OF TOBACCO IN FOREIGN COUNTRIES.

Tobacco is grown under a wide range of conditions in various parts of the world, although more than one-third of the total world production is in the United States. The other principal countries growing tobacco are India, Russia, Sumatra, Java, Hungary, Japan, the Philippine Islands, Germany, Cuba, France, Italy, Turkey, Brazil, and South Africa. To this list may be added Mexico, Porto Rico, Canada, China, Rumania, Serbia, Bulgaria, Greece, Belgium, and several other countries growing more than 5,000 acres. The diseases of tobacco which occur in these countries are of some interest to the producer in the United States, since with increasingly close commercial relations the importation of new and dangerous parasites is not at all unlikely. It seems quite probable that at least some of our diseases of tobacco have been introduced from foreign countries. A few diseases described in foreign literature are not yet known to exist in this country, and these should especially be guarded against.

Many of the foreign countries have investigated their plant diseases in little or no detail, so that serious troubles may exist about which we at present know nothing. It is also true that diseases

which are not serious in their native country may be much more so when introduced into other countries with different climatic conditions prevailing.

Tobacco diseases have been reported on in most detail from the Dutch East Indies, Italy, India, Dalmatia, Russia, France, and Germany. In general, foreign countries have most of the common diseases of tobacco which occur in the United States, although their occurrence as a serious problem is naturally very variable, as it is in the tobacco districts of the United States. It does not appear from the literature that the recently described bacterial leaf-spots of tobacco in this country exist elsewhere, with the exception of the possible occurrence of wild-fire in South Africa.

The diseases of tobacco are naturally described in foreign literature under a wide variety of names, and with the unsatisfactory description and diagnosis presented in many cases it is difficult to ascertain the relationship between the diseases as described from different districts. In the Dutch East Indies the bacterial wilt disease due to *Bacterium solanacearum* and the lanasziekte caused by *Phytophthora nicotianae* (our black-shank) seem to have been given most consideration. In Italy root-rot due to *Thielavia basicola* is said to be serious. Leaf-spot diseases are world-wide and have been attributed to a number of different parasites, many of which are not known in this country. Mosaic and frenching are common, as are a number of minor diseases attributed to nonparasitic agents or of unknown cause. Broom rape due to various species of Orobanche are common in southeastern Europe, as are also species of Cuscuta (dodders).

Among the more common fungous diseases not yet known to occur in this country is the powdery mildew due to Erysiphe to which at least five specific names have been given, though all probably are identical. Two species of Cercospora are reported, at least one of which is probably our American species. *Alternaria tenuis* Nees is frequently reported on tobacco in Europe, causing various types of troubles from seed bed to curing house, as are also various species of Sclerotinia. Parasitic species of Phyllosticta, Ascochyta, and Septoria on tobacco are apparently more common in Europe than in America, but none are probably of much economic importance. Ascochyta and Septoria have not been reported on tobacco in this country. A species of Olpidium is reported as causing a root disease of tobacco in Dalmatia, and two new species of Pythium are reported elsewhere as causing seed-bed troubles. On curing and fermenting tobacco, species of Botrytis, Penicillium, Aspergillus, Alternaria, Cladisporium, Sporidesmium, Pleospora, Sclerotinia, and Mucor are reported, but in most cases association of these with any of the damage occurring in these processes has not been definitely established. *Oospora nicotianae* is described as causing "must" in Italy.

Several diseases due to bacterial parasites have been described, particularly in France, but the relation of the organisms described to these diseases is still open to question. In the East Indies a bacterial leaf-spot (black rust) due to a bacterium (*B. pseudozoogloeae* Hon.) has been shown to exist. *Bacillus amylobacter* Van Teigh. is said to cause a bed rot in Italy.

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